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DEVELOPMENT OF ROCKET CONSTRUCTION AND ASTRONAUTICS IN THE U.S.S.R.

V. P. Glushko

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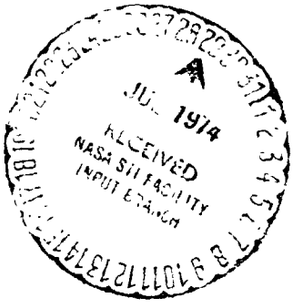

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16. Abstract

The book discusses the development of rocket construction and astronautics in the U.S.S.R. beginning with early research. The work of Russians in the field and Soviet institutes involved in rocket research are exhaustively reviewed. Basic discoveries of different types of rockets are presented, together with data on Soviet space probes.

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U.S.S.R. Academy of Sciences

V. P. Glushko

Development of Rocket Construction and Cosmonautics in the U.S.S.R.

Novosti Press Agency Publishers

Moscow, 1973

FROM THE EDITORS

The author of this book, Academician V. P. Glushko, is the founder of Russian rocket engine construction, one of the pioneers of rocket technology. He made theoretical and experimental studies on the most important problems of the creation and development of liquid-fuel rocket engines (LRE). He designed the first electrothermal rocket engine in the world (1929-1933) and the first Russian LRE's (1930-1931), as well as the Experimental Rocket Engine (ERE) family of LRE's, the ERE-1 to ERE-2 (1930-1938), the gas generators GG-1 and GG-3 using nitric acid and kerosene with water (1935-1940), and the rocket engine family of LRE's, RE-1 to RE-3 (1939-46), the family of rocket vehicles (1930-'933), and others.

He is an irreplaceable leader in the development of liquid-fuel and electrical engines installed on all Soviet rocket-carriers that have flown into space up to the present day.

Novosti Agency Publishers hope that the reader who is interested in problems of the development of rocket construction and space in the U.S.S.R. will glean much that is valuable by reading this book, which scientifically and reliably illuminates historical events.

Dedicated to the 50th anniversary of the creation of the Gaseodynamics Laboratory (GL)

(1921-1971)

THE U.S.S.R.--THE MOTHERLAND OF COSMONAUTICS

AT THE BEGINNINGS OF SOVIET ROCKET PRODUCTION AND COSMONAUTICS

STORMING SPACE BY ROCKET SYSTEMS

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LIST OF ABBREVIATIONS

ABBV. USED	RUSSIAN ABBV.	EXPANSION
ACG	GAT	address-current generator
AES	ICZ	artificial earth satellite
AI	AIIZ	Association of Inventors
AUASETS	AVIAVNITO	All-Union Aviation, Scientific Engineering and Technical Society
BI	BI	unknown
BM	BM	unknown
BSG	GPS	bandwidth shift generator
DO	KB	design office
EDB	OKB	experimental design office
EJ	OR	escape jet
ER	ERD	electrical rocket engine
ERE	ORM	experimental rocket engine
GL	GDL	Gaseodynamics Laboratory
GSJP	GIRD	Group for the Study of Jet Propulsion
JSRI	RNII	Jet Scientific Research Institute
LGSJP	LenGIRD	Leningrad Group for the Study of Jet Propulsion
LRE	ZhRD	liquid-fuel rocket engine
MMR	MMR	unknown
MR	MR	meteorological rocket
R	RS	rocket
RA	RA	unknown
RDA	RDA	unknown
RDB	RDB	unknown
RE	RD	rocket engine
RP	RP	rocket plane
RV	RLA	rocket vehicle
SADACC	OSOAVIAKhIM	Society for Assistance to the Defense and Aviation Chemical Industries of the U.S.S.R.
SSAI	GAISh	P. K. Shternberg State Astronomy Institute
SSIC	OIMSS	Society for the Study of Interplanetary Communication

THE U.S.S.R.--THE MOTHERLAND OF COSMONAUTICS

/5*

On October 4, 1957, the inspired labor of the Soviet people launched the very first artificial satellite into orbit around the Earth.

Thus began the space era in the history of mankind's development.

Progress in the creation of rocket-space systems and the penetration of man into space connected with it during the last 15 years has progressed at a rapid tempo and has placed an indelible imprint on many aspects of human activity.

The dream of penetrating space, man's striving to reach the stars, was born thousands of years ago. The first primitive powder rockets appeared in ancient times, at first as fireworks, and later for military use. The idea of using rockets for flight by man to heavenly bodies is mentioned in the novels of French authors: Cyrano de Bergerac's Voyage to the Moon (1649), Achille Eiro's Voyage to Venus (1865), Jules Verne's Around the Moon (1870). In Newton's work System of the World (1731), the launching of a body from the terrestrial surface into an earth satellite orbit, by transmitting to it the necessary velocity of motion, was described. The creation of an inhabitable, artificial earth satellite and its use for practical needs was described in the work of the American writer E. E. Hale, Brick Moon (1869-1870). The idea of creating artificial earth satellites with the help of rockets shot out of guns was first expressed by Jules Verne in the novel 500 Million Begums (1879).

The first known design of a piloted rocket flying machine, not in the fantasies of novelists, but scientifically developed, belongs to the revolutionary scientist N. I. Kibal'chich (1881). In 1893 the German inventor G. Gansvindt suggested a design for a passenger solid-fuel rocket for flight to the planets.

The founder of cosmonautics, the creator of a theory of rocket flight, and of the basic principles of the construction of rocket-space systems, and the author of the first scientific plans for penetration by man into interplanetary space and the conquest of space is K. E. Tsiolkovskiy. The work which he published in 1903, The Study of World Space by Jet Instruments, and its subsequent supplements, is a fundamental contribution to the storehouse of world science.

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*Numbers in the margin indicate pagination in the foreign text.

The theoretical researches of K. E. Tsiolkovskiy were later confirmed and supplemented by scientific studies both in the U.S.S.R. (about which more details will be related below), and abroad: in France by Robert Eno-Peltry (1913), in the U.S.A. by Robert Goddard (1919), in Germany by Hermann Oberth (1923), and by other outstanding scientists. /6

K. E. Tsiolkovskiy did not live to see the realization of his dream. The breakthrough into space was completed 22 years after the death of the great scientist.

More than half a century passed from the day of the publication of the classic work by K. E. Tsiolkovskiy to the noteworthy event in the history of mankind when, by the efforts and talent of the Soviet people, the fetters of earthly gravity were thrown off for the first time. Before man was opened a new, incomprehensible world of weightlessness, full of secrets and stars.

The flights of the first artificial satellites of the earth, sun, and moon, of the first automated stations to the moon, Venus, and Mars, the first reaching of the surface of the moon, of Venus, and Mars by unmanned stations, and the soft landing on these heavenly bodies, the photographing of the far side of the moon and the transmission to earth of a picture of the moon's panorama, the first flight around the moon and return to earth of an automated apparatus, the delivery by robot of lunar rock back to earth, the study of the moon's surface by an automated lunar vehicle, flights of the first male and female cosmonauts, alone and in groups, in one-passenger and multi-passenger satellite ships, the first emergence of a cosmonaut from a ship into cosmic space, the creation of the first experimental piloted orbital station, and many other achievements of the Nation of Soviets, engender in all Soviet people a rightful feeling of pride. The interest in how and when Soviet rocket production, which achieved by this time such a rapid development, began, in when, by whom, and what problems were raised and solved, is completely understandable.

This edition, presented in two parts, briefly illuminates the history of the development of Soviet rocket technology and cosmonautics. In the first part--"At the Beginnings of Soviet Rocket Production and Cosmonautics"--the history of the development up to 1945 is presented. The second part--"Storming Space by Rocket Systems"--describes the events beginning with the postwar period right down to our day.

AT THE BEGINNINGS OF SOVIET ROCKET PRODUCTION AND COSMONAUTICS

The development of solid-fuel rockets has its history in Russia. Without dwelling on the as yet little studied initial period of its development, we should mention that, in about 1680, in Moscow, a "Rocket Department" was begun, producing rockets in great quantity. In the 18th and 19th centuries, solid-fuel rockets were used in the Russian Army and in the Navy.

A great contribution to the development of a theory, structure, and technology of powder rockets was made by outstanding Russian artillerymen and scientists: A. D. Zasyadko (1779-1837), K. I. Konstantinov (1817-1871)--the leader of the St. Petersburg rocket factory, who wrote a fundamental work, "On Military Rockets" (1861), M. M. Pomortsev (1851-1916), N. I. Tikhomirov (1860-1930)--the founder of the Gaseodynamics Laboratory (1921), and many others. /7

In 1814 A. D. Zasyadko began working on the creation of various types of military rockets, and, already in 1817 possessing successful designs for rockets, he demonstrated their action in the pyrotechnics laboratory which he built specially in Mogilev. The works of A. D. Zasyadko and other inventors of military powder rockets led to the creation, in 1826, in St. Petersburg, of a permanent rocket institute with the purpose of mass production of rockets for the Russian army.

In 1834 the engineer K. A. Shil'der developed a design for an underwater boat-rocket launcher, armed with six rockets designed for launching from underwater or above-water positions.

K. I. Konstantinov, beginning in 1849, was commander of the St. Petersburg Rocket Institute, and from 1850 on, commander of the St. Petersburg Rocket Factory. In 1859-1861 he gave a series of lectures for artillery officers on military powder rockets. From 1867 on he headed the Nikolayevskiy Rocket Factory. K. I. Konstantinov laid the foundations of the science of military rockets. From 1847 on, he systematically worked on the study, perfection, and production of rockets, studied their ballistic properties, and made devices with a flight range of 4-5 km which were very advanced for the 19th century.

K. I. Konstantinov pointed out: "At every moment of combustion of the rocket components, the rate of motion transmitted to the rocket is equal to the rate of motion of the outflowing gases." Independently of K. I. Konstantinov, K. E. Tsiolkovskiy

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obtained this same equation and from it deduced the basic equation of rocket dynamics. K. I. Konstantinov authored a large number of scientific articles on various problems of technology and designed a number of artillery instruments: an electrical ballistics instrument for measuring the speed of flight of charges, an instrument for measuring the flight altitude of signal rockets, an optical range finder, a ballistic missile pendulum, etc. His chief printed works are articles in Artillery Journal for 1845-1867, and in Morskoi Sbornik (Naval Collection) during the years 1854-1866, the books Military Rockets (1857) and On Military Rockets, and lectures read at the Mikhailovsk Artillery Academy (1864).

M. M. Pomortsev from 1902 to the end of his days developed powder rockets with surfaces of various forms for stabilizing flight which achieved a range of up to 8-9 km, and also a pneumatic rocket. In flight tests of this rocket which he conducted at the Aerodynamics Institute in Kuchino, he used air compressed up to 100-125 atm in the steel chamber of the rocket. Into this air gasoline or ether was introduced as a fuel.

N. V. Gerasimov put in a great deal of labor working in 1909-1912 on the realization of his design for a gyroscopic rocket. /8

The instability of combustion of the black powder with which the rockets were equipped and its small degree of effectiveness stimulated the search for other powders which would not have these shortcomings. I. P. Grave for the first time suggested in 1915 the use in rockets of pressed, long-burning cartridges of smokeless gun cotton slab. In 1916 at the Shlissel'burg powder factory he produced them from a mass of gun cotton and tested cylindrical cartridges with a diameter of 70 mm. But the use of a volatile solvent hindered the achievement of stability of the properties and constancy of the geometry of these cartridges. A stable gun cotton powder in a nonvolatile solvent (trotyl, and, subsequently, nitroglycerine) was developed by S. A. Serikov and produced in the Gaseodynamics Laboratory.

N. I. Tikhomirov was an engineer-chemist, organizer and leader of the Gaseodynamics Laboratory (GL), and initiator of the development in the U.S.S.R. of rocket charges using smokeless powder. He occupied himself with the problem of creating powder rocket charges from 1894 on. In 1912 he presented a design which in 1916 was given a positive evaluation by experts, headed by N. Ye. Zhukovskiy. From March 1, 1921, the organization of the laboratory began. Having received funds and a two-story building from the War Department, he organized in Moscow a laboratory with shops (15 machines). The development of a cartridge smokeless powder with a stable solvent and experimental launchings of rockets took place in Leningrad. After the first successful

flights of rockets with smokeless powder, the Jet Laboratory of N. I. Tikhomirov in July 1928 was substantially expanded and received the title of GL.

This laboratory--the first Soviet rocket scientific-research and experimental-design organization--was brought under the Military Scientific Research Committee for the U.S.S.R. Revolutionary War Council. The GL was quartered at the Scientific-Testing Artillery Field near Leningrad, occupying half of a large, light, one-story building. In addition, the GL had at its disposal premises at a testing field for a mechanical shop, in the center of the city for control of the laboratory, in Grebnyi port (Vasil'evskiy Island) in the building of the Scientific Research Laboratory of the Naval Department for the production of shells of smokeless powder for rocket charges, at Komendantskiy airport, and at other places.

At the beginning of 1933 the GL consisted of 5 departments and shops, located in 6 places in Leningrad with a staff of about 200 people.

The development of powder rocket charges was concentrated in the first section of the GL, begun by N. I. Tikhomirov, and was carried out by the outstanding artillery engineers B. S. Petropavlovskiy, G. Ye. Langemak, V. A. Artem'yev, and others. The rocket charges of various calibrations which they developed with /9
smokeless powder for equipping the Army and the Air Force in 1932-1933 successfully passed testing-field and troop tests, and, later, after they were perfected in the Jet Scientific Research Institute (JSRI), were widely used with great effectiveness in 1941-1945 at the fronts of the Great Fatherland War and in the mobile rocket device called "Katyusha." By the end of the Great Fatherland War, 40 separate divisions, 105 regiments, 40 brigades, and 7 divisions of jet artillery which had mortar guard units were fighting.

In 1930-1933 in the GL rocket charges of 82 mm, 132 mm, 245 mm, and 410 mm caliber were developed, and also some of lesser calibers for auxiliary purposes. In all, in the GL by the end of 1933, 9 types of rocket charges had been developed and had passed official tests, as stated in the report of the Administration of Military Inventions to the Chief of Armaments of the Workers' and Peasants' Army, M. N. Tukhachevskiy.

In 1927-1933 in the third department of the GL a powder rocket start for light and heavy aircraft was developed (U-1, TB-1, TB-3). Thus, in the state tests in 1933 the TB-1 bomber, equipped with starting rockets using smokeless powder, the takeoff run of the aircraft was shortened 77%.

V. A. Artem'yev (1885-1962) occupied himself from 1915 with developing rockets using smoke powder. In 1921-1933 he was one of the chief assistants at the GL, and from 1934 on--of the JSRI. He built powder engines for the Leningrad Group for the Study of Jet Propulsion (LGSJP) rockets (1931-1933). Many of his designs for rockets using smokeless powder passed official tests. B. S. Petropavlovskiy (1898-1933) from 1929 on worked in the GL, and in 1930-1931 was its chief. G. E. Langemak (1898-1938) worked in the GL, and in 1934-1937 was deputy director and chief engineer of the Jet Scientific Research Institute.

After N. I. Tikhomirov and B. S. Petropavlovskiy, the chiefs of the GL were N. Ya. Il'in (1931-1932) and I. T. Kleimenov (1932-1933), who put much work into the development of rocket production in the U.S.S.R.

A whole galaxy of inventors and designers had worked over a long period on the possibility of applying the jet principle of motion to the scientific resolution of the problem of human air flight. In 1849 the military engineer I. I. Treteskiy (1821-1895) developed designs for three lighter-than-air flying machines which could move with the help of the reaction of a stream of gas or steam, and in 1866 Admiral N. M. Sokovnin (1811-1894) of the Russian fleet in the work Airship proposed a jet aerostat which "should fly by a method similar to that by which a rocket flies."

The retired artillery captain N. A. Teleshevyy (1828-1895) in 1867 received a patent for a jet aircraft "Del'ta," and in 1887 the Kievan inventor F. R. Geshvend in his brochure "General Basis for a Mechanism of an Aerostatic Steamer (Steam Flying Vehicle)" proposed a design for a flying machine with a steam jet engine. The concentric nozzle heads developed by F. R. Geshvend later became known under the name of Melo nozzles. /10

The development of a design for a rocket flying machine for human flight was begun for the first time in Russia by N. I. Kibal'chich (1853-1881), the well-known "Narodnaya Volya" revolutionary.

N. I. Kibal'chich seriously studied the literature on explosive substances and powders in Russian, French, German and English, and displayed exceptional inventiveness in his work. According to the testimony of contemporaries of Kibal'chich, "it would not be an insult to say to the government technicians that they could learn a great deal from Kibal'chich--with his enormous erudition for more than two years he had in his hands an excellent laboratory and such a series of experiments which even the experts who disputed Kibal'chich in court did not approximate . . . He became very well acquainted with all the properties of nitroglycerine preparations and attained true artistry in the use of

them." Before his arrest, N. K. Kibal'chich headed the laboratory of the Executive Committee of "Narodnaya Volya." The talented inventor, who gave his life in the struggle against tsarism, during his short imprisonment before his execution in St. Petersburg in March, 1881, developed a "Design for a Soaring Instrument," for a powder rocket flying machine. In N. I. Kibal'chich's design such technical problems as the building of a powder rocket engine, the guidance of a rocket apparatus by changing the angle of inclination of the engine, a programmed regime of combustion for constantly rising or hovering at an altitude, ensuring the stability of the apparatus, and a number of other factors, were considered.

Two years later, in 1883, K. E. Tsiolkovskiy (1857-1935), in the work Free Space describes for the first time his spaceship with an engine using the jet principle. In 1895 in Moscow his essay "Fantasies about the Earth and Heaven and Effects of Universal Gravitation", in which the idea of building an artificial earth satellite were again expressed, was published.

In the May number of the St. Petersburg journal Scientific Observer for 1903 K. E. Tsiolkovskiy's classic work, "Study of World Space by Jet Instruments," which showed what heights man's genius can attain, was printed. With extreme clarity and accuracy the bases of the theory of rocket flight are presented for the first time, and the principles of the construction of a rocket and a rocket engine using liquid fuel are described. Later the scientist published very valuable additions to this work under the same title (St. Petersburg, 1911 and 1912; Kaluga, 1914 and 1926). In them the plan for man to go out into space, the colonization of interplanetary expanses, the operation of heavenly bodies, and the use of the practically limitless energy of the sun, were presented. Here also K. E. Tsiolkovskiy described an idea for an electrical rocket engine in which the products of discharge are charged particles, and also pointed out the advantage of building a rocket engine with the use of atomic energy. But this was a distant prospect. First of all the scientist proposed constructing rockets using liquid fuel, the composition of which, in his opinion, could include, as oxidizers, liquid /11
oxygen, ozone, nitrogen pentoxide, and, as fuel, liquid hydrogen, methane, carbons, benzol, benzene, turpentine, and other substances.

In the following years K. E. Tsiolkovskiy wrote a number of other studies devoted to problems of flight into space.

The scientist and inventor S. S. Nezhdanovskiy (1850-1940), who, as early as 1880, began to think about the possibility of a device for a jet flying machine, and, in 1882-1884, spent time studying the problem of the energetics of jet engines, worked on

the problem of jet flight, and discussed in a manuscript the use of an explosive mixture consisting of two liquids--fuel (kerosene) and an oxidizer (nitrogen dioxide, nitric acid) as a source of energy.

In subsequent years the inventors A. V. Eval'd, A. P. Fedorov, and many others worked on the problem of jet flight in the U.S.S.R.

A. P. Fedorov (born in 1872) published in 1896 in St. Petersburg the work, A New Principle of Aerostation, in which he described the structure of a rocket apparatus for moving in space, excluding the atmosphere as a support medium. As working fluids the following were proposed: steam, compressed air, or carbonic acid. This work suggested to K. E. Tsiolkovskiy a deeper investigation, which concluded with the creation of the bases of rocket dynamics.

Some elements of the theory of the jet engine in relation to sea vessels were developed by the father of Russian aviation, N. Ye. Zhukovskiy (1847-1921). This is shown by his articles "On the Reaction of Effluent and Influent Liquids" (1882, 1885) and "Towards a Theory of Ships Set in Motion by the Force of the Reaction of Water" (1908).

The great Russian scientist I. V. Meshcherskiy (1859-1935) in the report "One Particular Case of the Theorem of Gyul'den," read in 1893 at the St. Petersburg Mathematics Society, presented his studies on the theory of the movement of bodies of variable mass. In the published work Dynamics of the Point of Variable Mass (1897), I. V. Meshcherskiy cited as an example a motion equation of a rocket with vertical takeoff. These studies were supplemented by the article "Equation of Motion of a Point of Variable Mass in the General Case" (1904), in which he gave a general theory for the initial motion of a point of variable mass for the case of fall-away (or combination) of particles, and then for the case of simultaneous fall-away and combination of particles.

In 1918 his article, "A Problem from the Dynamics of Variable Masses," devoted to the movement of a system of points with variable masses, was published. Thus I. V. Meshcherskiy set forth the basic equations of rocket dynamics.

In 1915 in Petrograd the remarkable book of the well-known popularizer of science, Ya. I. Perel'man (1882-1942), Interplanetary Journeys, was published, which ran to ten editions over a 20-year period. He wrote it on the basis of a report under the same title, read in 1913. In this work all the methods of flight /12
of man into space known in the literature were reviewed from the

position of scientific criticism. Here are the canon of Jules Verne, and the "favorite" of Herbert Wells, a hypothetical material impenetrable by the forces of gravity and therefore not harmed by them; here also are the screens of light pressure using the repellent action of the sun's radiation, and finally, Tsiolkovskiy's rocket. As a result of critical analysis, Ya. I. Perel'man shows that a rocket is the only true way for man to go out into space.

To Ya. I. Perel'man also belong the scientific popular works, Flight to the Moon (1924), Tsiolkovskiy (1924), By Rocket to the Moon (1930), To the Stars on A Rocket (1933), and others.

In the prerevolutionary period of the development of rocket science and technology in Russia, the conservatism of the tsarist government blocked the way of the new and the progressive. Materials with the prophetic scientific quests of N. I. Kibal'chich lay in the archives of the tsarist secret police until the revolutionary days of 1917, and the brilliant studies of K. E. Tsiolkovskiy found no support. Only after the establishment of Soviet power was N. I. Tikhomirov granted the opportunity to organize a jet laboratory.

The Great October Socialist Revolution was a turning-point in the development of Soviet rocket production. At this time K. E. Tsiolkovskiy was 60 years old. During the 18 years of his life under a Soviet government he completed and published many theoretical works, significantly more than in the prerevolutionary period.

Developing and adding to the theoretical studies of K. E. Tsiolkovskiy, his students and followers conducted experimental work on rocket technology in specially built laboratories, institutes, and design bureaus.

K. E. Tsiolkovskiy has deservedly entered the history of the conquest of space as the founder of the theory of jet motion and the originator of the principles on which the development of this new department of science and technology is founded, as an inspired propagandist for space flight, an inventor, a thinker, and a great scientist-patriot.

In 1917-1919 the talented researcher Yu. V. Kondratyuk (1897-1942) completed the first stage of work on the basic problems of rocket motion, expounded in the work To Those who will Read in Order to Build. In 1929 he published in Novosibirsk a theoretical study, The Conquest of Interplanetary Space, partly repeating and supplementing the work of K. E. Tsiolkovskiy. A number of problems of rocket dynamics and rocket construction

found a new solution in these works. Independently of K. E. Tsiolkovsky, and without being acquainted with his studies, Yu. V. Kondratyuk by an original method deduced the basic equations for the motion of a rocket. In his works the following problems are discussed: the most favorable trajectories for space flights from the viewpoint of energy, the theory of multistage rockets, intermediate interplanetary fueling rocket bases in the form of satellites of the planets, economical landing of rockets on a planet by using braking by the atmosphere, and many others. He /13
proposed flights to the moon and the planets, going out into a satellite orbit and with subsequent separation of the small takeoff and landing ship as energetically most suitable. His proposal to use the gravitational field of the heavenly bodies encountered for pre-acceleration or braking of spaceships in flight in the solar system is also prophetic. He suggested several metals, metalloids, and their hydrogen compounds, for example, boron hydride, for use as fuel in the engines.

Another great representative of the Soviet school of rocket construction was F. A. Tsander (1887-1933), who dedicated his life to the solution of problems of rocket technology. From 1907 on he began to pursue his first theoretical studies, and, somewhat later, his engineering calculations. In 1921 Tsander presented a report on the design of a spaceship-airplane at the Moscow Conference of Inventors, and in 1924 he published in the journal Technology and Life an article entitled "Flights to Other Planets," in which he set forth one of his basic ideas--the combination of a rocket with an aircraft for takeoff from the earth with the subsequent burning in flight (in the combustion chamber of the rocket engine) of the structure of the aircraft as fuel in order to increase the flight range of the rocket.

In 1930 F. A. Tsander constructed the first Soviet laboratory jet engine of a new type from an ordinary blowtorch, calling it EJ-1 (experimental jet). The engine worked on compressed air and benzene and developed a thrust of up to 145 kg. Later he developed liquid rocket engines for work using liquid hydrogen and benzene.

The following problems were reviewed in F. A. Tsander's manuscripts: the use of the atmosphere on takeoff and landing, the possibility of flights directly into interplanetary space with the help of solar energy, the determination of the trajectory of spaceships, and a number of other problems connected with space flights.

His theoretical studies of various problems of the arrangement and space flights of rocket aircraft, the search for optimal thermodynamic cycles of jet and air-breathing jet engines, and also his proposals on the burning of certain metals and their

alloys were summarized in the book The Problem of Flight Using Jet Apparatuses, which was published in 1932.

The great Soviet aerodynamicist V. P. Vetchinkin (1888-1950) from 1921 on worked on problems of jet flight within the bounds of the atmosphere and in interplanetary space. In the period 1921-1925 he delivered reports on this subject, and in 1925-1927 he worked out the dynamics of flight of winged missiles and jet aircraft, published in his articles: "The Vertical Motion of Rockets" (1935), "The Flight of a Winged Missile at Supersonic Speeds" (1937), etc. With his public work of a scientific-technical character, V. P. Vetchinkin promoted the propagation and development of ideas of interplanetary flights and the development of work on rocket technology. /14

In April, 1924, in Moscow at the Military-Scientific Society of the Academy of the Air Fleet (now the N. Ye. Zhukovskiy Military-Air Engineering Academy) a Section of Interplanetary Communications was created. In this same year it was transformed into the Society for the Study of Interplanetary Communications (SSIC) under the chairmanship of G. M. Kramarov. The Society had a set of rules and comprised about 200 members. In its work K. E. Tsiolkovskiy, F. A. Tsander, V. P. Vetchinkin, and others took part. The SSIC existed for about a year and played a notable role in propagandizing the ideas of space science in the U.S.S.R.

In 1925 Academician D. A. Grave formed in Kiev a circle for the study and conquest of space, in the scientific-technical council of which Academician B. I. Sreznevskiy, Ye. O. Paton, K. K. Seminskiy, V. I. Shaposhnikov, and other scientists and engineers were included. By the efforts of this circle and the section of inventors of the Kiev Association of Engineers and Technicians, there was organized and opened on June 19, 1925, the first exhibition dedicated to the problem of studying interplanetary space. This exhibit achieved success; the visitors heard lectures by scientists on the conquest of space.

In the U.S.S.R. numerous circles for the study of problems of space flights began to arise. On June 14, 1925, Academician D. A. Grave congratulated these enthusiasts of rocket technology.

In April-June, 1927, in Moscow, the Association of Inventors, abbreviated AI, organized the first international exhibit of designs for interplanetary flying machines. Here the works of K. E. Tsiolkovskiy (U.S.S.R.), R. Goddard (U.S.A.), H. Oberth, V. Gomann, and M. Val'e (Germany), F. A. Tsander (U.S.S.R.), R. Eno-Peltry (France), and many others were exhibited.

At the end of 1928 in Leningrad under the Institute of Engineers of Methods of Communication (now the Academician V. N.

Obraztsov Leningrad Institute of Engineers of Rail Transport) a Section of Interplanetary Communications was organized. The deacon of the Department of Aerial Communications of this Institute, Professor N. A. Rynin (1877-1942), was named chairman of this Section, and its members were instructors, engineers, and students.

In 1929 N. A. Rynin published a proposal to organize a national or international scientific-research institute of interplanetary communications, setting forth in detail the structure and tasks of this institution. N. A. Rynin did scientific work in the field of rocket technology and studied the effects of accelerations in the creation of inertial overloads on the organisms of animals, but he is better known as the author of the only encyclopedia of international communications of its kind, published in 9 books in 1928-1932. He scrupulously collected and described the myths and legends dedicated to the idea of flight into space which had been preserved since very ancient times, the fantasies of novelists, and the theoretical and experimental studies of scientists. A separate book in the encyclopedia was dedicated to an analysis of the scientific heritage of K. E. Tsiolkovskiy. For its time this work was a valuable aid for all who were beginning to work in the field of rocket technology. This unique work concludes with a broad bibliography. The three-volume work consists of 9 issues: Vol. 1, Issue 1--Dreams, Legends, and First Fantasies; Vol. 1, Issue 2--Spaceships in the Fantasies of Novelists; Vol. 1, Issue 3--Radiant Energy in the Fantasies of Novelists and the Schemes of Scientists; Vol. 2, Issue 4--Rockets and Engines of Direct Reaction; Vol. 2, Issue 5--Theory of Jet Propulsion; Vol. 2, Issue 6--Superaviation and Superartillery; Vol. 3, Issue 7--The Russian Inventor and Scientist K. E. Tsiolkovskiy. His Biography, Works, and Rockets; Vol. 3, Issue 8--The Theory of Space Flight; Vol. 3, Issue 9--Astronavigation, Chronicle and Bibliography. /15

Despite the fact that the collected material was not always subjected to sufficient critical analysis, its historical-bibliographical value is without doubt. After the publication of this encyclopedia, N. A. Rynin collected much new interesting material and was preparing a second, significantly expanded edition. But it was not completed. N. A. Rynin died in 1942.

Since 1934 scientific and numerous scientific-popular works on cosmonautics by A. A. Shternfel'd have been published. They have been published in 31 languages in 35 countries. His chief works were Introduction to Cosmonautics (1937), Artificial Earth Satellites (1956, 1958), and others. A. A. Shternfel'd was twice laureate of international prizes for cosmonautics awarded him in 1934 and 1963.

The beginning of experimental studies in the U.S.S.R. on the creation of electrical and liquid-fuel rocket engines (LRE) dates to May 15, 1929, when, for this purpose, on the suggestion of the author, the first experimental design organization within the Gaseodynamics Laboratory (the second division of the GL) in Leningrad was formed and began practical activity.

Since 1921 the author had been intrigued by problems of cosmonautics. In 1930 he proposed and later studied as components of fuel for LRE nitric acid, solutions of nitrogen tetraoxide in nitric acid, tetranitromethane, hydrogen peroxide, chloric acid, beryllium, a three-component fuel--oxygen with hydrogens and beryllium, a powder with dispersed beryllium; he developed a shaped nozzle and a ceramic heat-insulating combustion chamber with a layer of zirconium dioxide (1930), and a cardan suspension of an LRE for control of rocket flight (1931). In 1931 he proposed, and from 1933 on, introduced into the LRE, chemical combustion and self-igniting fuel; developed for an LRE a nozzle system with a thrust of 300 kg of piston dual action driven by gas removed from the combustion chamber (1931-1933), and a turbo-nozzle system with centrifugal nozzles (1933); proposed methods for increasing the effectiveness of fuels for an LRE by increasing their density by deep cooling and the introduction of a heavy inert admixture. At the same time (in 1933) he proposed as an /16
oxidizer solutions of fluorine in oxygen, fluorine-hydrogen fuel, solutions of kerosene in pentaborane as a propellant, and many others.

In 1929-1930 in the second department of the GL the working capacity in principle of an electrical rocket engine (ERD) was proven for the first time theoretically and experimentally, using as working fluid hard or liquid conductors (constantly fed by metal wires or liquid streams), exploded with the assigned frequency by an electric current in a chamber with a nozzle.

The work on an electrical rocket engine begun in the GL found its sequel in our day. For the first time in the world the Soviet Union in real flight conditions in space orbits used ion and plasma ERD's on the "Voskhod-1" ship and the "Zond-2" unmanned station, which were launched in 1964.

An ERE (experimental rocket engine) with a thrust of 6 kg was tested using the previously prepared mixture of liquid oxidizers and fuel, ignited in the combustion chamber with a nozzle; the ERE-1 with a thrust of 20 kg, the ERE-2 and the subsequent engines--with separate feeding of liquid oxidant and fuel. In 1931 46 stand firing tests of the first Soviet liquid-fuel rocket engines, working on nitrogen tetroxide with toluol and benzene, were conducted.

In 1932 the constructions of experimental engines (from the ERE-4 to the ERE-22 inclusive) were developed for seeking a type of ignition, method of launch, and systems of blending in a test with various fuels. In 53 stand tests of these engines in 1932, liquid oxygen, nitric tetroxide, nitric acid, solutions of nitric tetroxide in nitric acid were used as oxidants, and as fuel--benzene, benzol, toluol, and kerosene. In 1933, engines (from ERE-231 to ERE-52 inclusive) were created and tested on the stand with pyrotechnical and chemical ignition using nitric acid-kerosene fuel. Experimental ERE-50 engines with a thrust of 150 kg and an ERE-52 with a thrust of 300 kg in 1933 passed official stand tests.

By the end of 1933 the basic difficulties on the path of creating reliably working liquid-fuel rocket engines with good response have been overcome in the GL. Operatively convenient fuels and stable construction materials were chosen, systems of pyrotechnical and chemical ignition were developed, the construction of centrifugal fuel burners, a system of regenerative-running cooling of the fuel of the nozzles with spiral ribbing, cooling of the chambers by an internal fuel screen and other developments had occurred. The working pressure in the combustion chamber was 20-25 atm, the specific impulse up to 210 sec, and the thrust up to 300 kg. The engines allowed multiple launchings. For example, an ERE-50 engine produced in one prototype successfully passed in 1933 three finishing and reduced engine-life tests, later, in 1934, five stand tests with rocket C5 constructed by the Group for the Study of Jet Propulsion (GSJP), for which it was designed, /17 and in a launch at the Nakhabinskiy proving ground in Moscow in a regime of lowered thrust worked all the fuel out of the tanks of the rocket without failure of its feeding system and without any provision for a necessary pressure for feeding the fuel. The engine maintained its working capacity after 10 trials lasting a total of 314 seconds.

The ERE-52 engine was distinguished in that time for its great thrust, and was designed for naval torpedos, aircraft, and for the RV-1, RV-2, and RV-3 rockets which were developed in the GL. One may judge the reliability of this engine by the fact that one prototype during 29 launches operated for 533 seconds, developing a thrust of 300-320 kg, and completely maintained its working capacity.

In 1932 in the GL, on a commission for the armed forces, the development of experimental accelerators in the form of LRE's for the I-4 aircraft was begun, with the purpose of communicating auxiliary thrust to aid the propeller-driven group.

The arms chief of the Red Army, M. N. Tukhachevskiy, under whom the GL was subordinated, was present at the test of the LRE

and in 1932 wrote to the chief of the Military Technical Academy of the Workers' and Peasants' Army: "Especially important prospects are connected with the experiments of the GL on a liquid-fuel jet engine, which they recently succeeded in building in the laboratory."

V. P. Vetchinkin, who was present in 1932 at the test in the GL of the ERE-9 engine using oxygen-benzene fuel, wrote: "In the GL the chief part of the work has been done for realizing a rocket--a jet engine using liquid fuel . . . From this point of view, the achievements of the GL (chiefly of engineer V. P. Glushko) must be considered brilliant."

In the development of the ER and the LRE in the GL the talented engineers and technicians A. L. Malyy, V. I. Serov, Ye. N. Kuz'min, I. I. Kulagin, Ye. S. Petrov, P. I. Minayev, B. A. Kutkin, V. P. Yukov, N. G. Chernyshev, F. A. Timofeyev, N. M. Mukhin, I. M. Pan'kin and others took active part.

The subdivision of the GL for the development and testing of the ER and LRE in 1929-1930 was located in Leningrad at the Electrophysical Institute, in 1930-1933, at the Scientific Testing Artillery Proving Ground in Rzhevka (near Leningrad) and in 1932-1933 in the building of the Main Admiralty and in the Johannes Ravelin of the Petropavlovsk Fortress (Leningrad). One half of the building at the Rzhevsk proving ground was occupied by the GL, and in the other half there was located a well-equipped chemical laboratory in which studies were conducted on fuels for liquid-fuel rocket engines.

In the fall of 1931 under the Society for Assistance to the Defense and Aviation Chemicals Construction of the U.S.S.R. (SADACC), Moscow and Leningrad groups were organized for the study of jet propulsion (GSJP), embracing on a voluntary basis rocketry enthusiasts. Among the organizers and active workers of the Moscow GSJP, created on November 18, 1931, were Г. A. Tsander (its first leader), S. P. Korolev, who soon replaced Tsander in the post of leader, B. I. Cheranovskiy, V. P. Vetchinkin, and Yu. A. Pobedonostsev, and also representatives of the public. The Moscow GSJP developed widescale lecture propaganda, and in 1932 /18
organized courses on the theory of jet propulsion and began work on designing the LRE aviation EJ-2 and the RP-1* rocket plane.

The Moscow GSJP, which received the title of central, gave aid to groups and circles for study of jet propulsion in other cities of the U.S.S.R. In 1934 the propaganda and educational functions of the Moscow GSJP were abandoned, and it was

*Translator's note: Expansion not known.

transformed into the Jet Group of the Central Council of SADACC, which successfully continued work until the end of the 30's and created a number of original, small experimental rockets.

Among the organizers and activists of the Leningrad GSJP formed on November 13, 1931, were Ya. I. Perel'man and N. A. Rynin, V. V. Razumov (1890-1967), the first chairman of the Leningrad GSJP, the engineers A. N. Shtern, Ye. Ye. Chertovskoi, the physicists M. V. Gazhala, I. N. Samarin, M. V. Machinskiy, and representatives of the public. In 1932 more than 400 people were members of the Leningrad GSJP. Workers of the Gaseodynamics Laboratory, for example, B. S. Petropavlovskiy, V. A. Artem'yev, and others provided much assistance in the organization of the Leningrad GSJP. The Leningrad GSJP actively campaigned for rocket technology, organized demontrational launches of small powder rockets, developed a number of original designs for experimental rockets (a photo rocket, a meteorological rocket, etc.), in particular, the rocket of Razumov-Shtern with a rotating LRE. In 1932 the Leningrad GSJP started courses on the theory of jet propulsion. In 1934 the Leningrad GSJP was transformed into the Section of Jet Propulsion, which, under the leadership of M. V. Machinskiy, continued propaganda work, conducted experiments on the influence of g-loadings on animals, and, right up to the beginning of the Second World War, developed and tested model LRE's and rockets of original design.

Following the example of the Muscovites and the Leningrad people, a movement for the organization of local GSJP's developed in Khar'kov, Baku, Tiflis, Arkhangel'sk, Novocherkassk, Bryansk, and other cities. The propaganda activity of F. A. Tsander, N. A. Rynin, V. P. Vetchinkin, V. O. Pryanishnikov and others brought a large proportion of participation into this movement.

In June, 1932, the Presidium of the Central Council of SADACC adopted a resolution for creating, in Moscow, on the base of the GSJP, an experimental organization for the development of rockets and rocket engines. For the work of the GSJP, funds and permanent premises were granted (the basement of house No. 19 on Sadovo-Spasskaya Street). The Chairman of the scientific technical council of the Moscow GSJP, S. P. Korolev (1906-1966), who was later the famous chief designer of rocket-space systems, was appointed its chief. The brigade of F. A. Tsander, up to this time working on a volunteer basis in the Moscow GSJP on the design of an engine installation with LRE, the EJ-2, for the rocket plane RP-1, was accepted on the staff. From August 1932 on the BSJP was financed in addition by the Board of Military Inventions of the WPA. Later three more design brigades were formed: for developing liquid-fuel ballistic rockets, for developing ramjet engines and gaseodynamic testing equipment, and for developing rocket planes and winged missiles. M. K. Tikhonravov, /19

Yu. A. Pobedonostsev, and S. P. Korolev led these brigades. In addition, a production brigade (shop) and a testing station were organized.

Other talented engineers who made a worthy contribution to the development of Soviet technology also worked in the GSJP: A. I. Polyarnyy, V. S. Zuyev, Ye. S. Shchetinkov, I. A. Merkulov, M. S. Kisenko, Ye. K. Moshkin, and many others.

The collective of this organization, relying on the scientific heritage of Soviet scientists, started on problems of experimental rocket construction.

In the summer of 1932 and in January 1933 in the GL the first meetings of workers of the laboratory with the leading workers of the GSJP who had come from Moscow took place--its chief S. P. Korolev, deputy Ye. S. Parayev, engineers F. A. Tsander, M. K. Tikhonravov, Yu. A. Pobedonostsev, and others. They demonstrated the operation of a liquid-fuel rocket engine on the stand. Thus occurred the meeting of workers of the GL with the Moscow rocket builders, which formed the beginning of further joint work. For a third of a century engines built by the school of talented engine builders which grew up on the base of the Leningrad Gaseodynamics Laboratory were installed on all the winged missiles developed by S. P. Korolev, the aircraft rocket engine installations, the intercontinental distant action and intracontinental rockets, the powerful meteorological and geophysical rockets, and also on all space rockets.

In 1933 at the testing field in Nakhabino near Moscow the workers of the GSJP launched rocket 09, built under the guidance of S. P. Korolev according to the design of M. K. Tikhonravov--the first Soviet rocket using hybrid fuel. Its starting weight was 19 kg, fuel weight was 5 kg, length, 2.4 m. The engine developed a thrust of 25-33 kg, the pressure in the combustion chamber was 5-6 atm, and it operated on liquid oxygen, fed into the chamber by the pressure of its own steam, and hardened benzene, which in the amount of 1-1.5 kg was placed in the combustion chamber. The launch was achieved from vertical guides. In the first flight on August 17, 1933, an altitude of about 400 m was attained, limited by the burn-out of the engine. The flight lasted 18 seconds. In the second launch, in the fall of 1933, after rising approximately 100 m, the engine exploded, and in 1934 this rocket (with the index 13) made a number of successful flights to altitudes of up to 1,500 m.

In the GSJP two LRE's constructed by F. A. Tsander were designed: the EJ-2, which was designed for installation on the tailless rocket glider RP-1, designed by B. I. Cheranovskiy, and an engine with an index of 10 for the GSJP-10 rocket. The first

liquid-fuel rocket engine designed by F. A. Tsander (EJ-2) with a projected thrust of 50 kg, cooling of the nozzle by water, and a combustion chamber with gas-forming oxygen, was built in the GSJP in December, 1932, and tested with oxygen-benzene fuel in March, 1933, without the participation of its designer, who died in that same month. In the first tests the engine was destroyed. The EJ-2 was redesigned by pupils of Tsander, the benzene was replaced /20 by ethyl alcohol for lowering the temperature of the gases and facilitating the cooling, ceramic facing of the chamber was introduced, and the engine code was changed to 02.

The LRE-10 engine with a combustion chamber of pear-shaped form, cooled by oxygen with fuel components of liquid oxygen and benzene, was developed from January 1933 on. In the first tests (August, 1933) the burn-out of the chamber necessitated a reworking of the design and the replacement of benzene with alcohol. From October 1933 on, tests were conducted which indicated a thrust of about 70 kg, a specific impulse of 162-175 sec, pressure in the combustion chamber of 8-10 atm, duration of performance of 16-22 sec, with a fuel of liquid oxygen and 78% ethyl alcohol.

On November 25, 1933, the first Soviet liquid-fuel rocket GSJP-10 with engine 10, built by the GSJP under the leadership of S. P. Korolev, was launched. The initial studies of the project were executed by F. A. Tsander. The starting weight was 29.5 kg, weight of fuel 8.3 kg, length of the rocket 2.2 m, its fuel feeding by displacement. On launch the rocket took off vertically to an altitude of 75-80 m, then, as a result of destruction of the engine casing, sharply deviated from the vertical and fell a distance of about 150 m from the starting place. The design of the GSJP-10 was developed in the more perfected Soviet rockets built in 1935-37. The subsequent work with Tsander's engine was done by his students, but it did not attain such a level as would ensure their development.

In the GSJP, other noncontrollable rockets, the 07 and 05, were built by M. K. Tikhonravov and were subsequently tested. Under the leadership of Yu. A. Pobedonostsev schemes for a direct-current air-breathing jet engine were worked out and a wind tunnel with supersonic flow speeds, exceeding the speed of sound by 3.2 times, was built.

As a result of the activity of the GSJP, which lasted as an organizer-developer for almost 1½ years, the results of flight tests of the first Soviet rockets helped to clarify the basic trend for further studies.

In the course of time, the demand for the solution of problems of rocket construction became more urgent, and the necessity of imparting more scope to this work was felt more sharply. In 1931 a proposal was introduced for the immediate reorganization of the Gasodynamics Laboratory into a Gasodynamics Institute with an emphasis on work on rockets using liquid fuel. In April, 1932, the Leningrad GSJP addressed a proposal to M. N. Tukhachevskiy on the organization of the Jet Scientific Research Institute on the base of the Leningrad GSJP, which would embrace more than 400 people interested in jet propulsion. The SADACC and the GSJP in Moscow also actively supported the idea of the creation of such an institute. In the course of 1932-1933, M. N. Tukhachevskiy, V. V. Kuybyshev, K. Ye. Voroshilov, G. K. Ordzhonikidze, and many others occupied themselves with the problem of the organization of this institute. On September 21, 1933, the first Jet Scientific Research Institute (JSRI WPA) on the base of the GL and the Moscow GSJP was organized in Moscow.

I. T. Kleymenov was appointed chief of the Institute, and, /21
as deputy chief, S. P. Korolev, and, from January 1934 on, the position was occupied by G. E. Langemak. Up to the end of 1937 I. T. Kleymenov (1898-1938) and G. E. Langemak, who headed the previous GL, led the JSRI, putting much energy and talent into the development of rocket technology in the U.S.S.R.

The Institute was transformed into an industry. By decree of the Council of Labor and Defense of October 31, 1933, which began with words: "Considering the existing achievements and the enormous prospects for the use of jet engines and especially of liquid-fuel jet engines . . ."

The collective of the institute maintained close ties with K. E. Tsiolkovskiy. The subject matter of the JSRI embraced all the chief problems of rocket technology. Within the walls of the institute a creative collective was formed which built a number of experimental ballistic and winged rockets and engines for them.

In 1934-1938 models of a number of rockets, for example, 06, 13, RDB-01, 48, 216, 217, and others, were tested in flight. In 1939 flight tests of the winged rocket 212 designed by S. P. Korolev with an ERE-65 engine were made. In the JSRI broad studies were conducted on the building of winged missiles and other work which had great significance for the rise and development of Soviet rocket technology. In 1937-1938 fuel tests of the RP-318 rocket plane designed by S. P. Korolev with the liquid-fuel engine ERE-65 were made, and in 1940 the pilot V. P. Fedorov made a flight on this rocket plane with an RDA-1-150 engine, which was a modification of the ERE-65. In 1942 the pilot G. Ya. Bakhchivandzhi made a takeoff and flight on the first Soviet

rocket aircraft, the BI-1, developed by A. Ya. Bereznyak and A. M. Isayev under the guidance of V. K. Bolkhovitinov; a liquid-fuel rocket engine D-1-A-1100, with a thrust of 1,100 kg, designed by the JSRI, was installed.

In the JSRI a broad and varied program of research was conducted. Here the finishing of 2-caliber powder rocket charges--R-82 and R-132--designed for military aircraft, was completed. On May 28, 1939 the Japanese aggressors suffered the... effect of rocket charges (R-82) in the region of the Khalkhin-Gol River. The legendary attack aircraft designed by S. V. Il'yushin which were armed with R-82's and R-132's were not called "the black death" accidentally by the hitlerites. These shells were also installed on the Yak and La fighters.

Work on the creation of rocket shells, basically executed in the GL, was completed in the JSRI. As a result of the efforts of many specialists, by the beginning of the Great Fatherland War the BM-13 rocket installation was built within the walls of the JSRI.

The brainchild of Soviet scientists, the BM-13, with M-13 shells, affectionately called "Katyusha" among the people, began to threaten the Fascists in 1941. The first salvo of "Katyushas" was made on June 14, 1941, on the railroad junction of Orsh. With this awesome weapon during the Great Fatherland War a great number of the enemy's men and equipment were destroyed.

The rocket artillery built in the JSRI, perfected and serially produced by factories, threatened the enemy on all fronts in the Great Fatherland War. Thus Soviet rocket scientists made their contribution to the routing of Hitlerite Germany. /22

Another significant trend in the work of the JSRI was the development of systems of control which were designed, produced, and installed on rockets, and passed flight tests. In such systems of control the instrument BSG-2 on the rocket 216, the instrument ACG-1 on the rocket 201, instruments BSG-3 and RA-2* on rockets 212 and 609 must be included. These instruments were gyroscopic autopilots. Thanks to them, automatic takeoff of rockets from a catapult cart was developed, and stable flight was achieved in the initial sector of the flight trajectory.

Turning backward somewhat, we shall note that in 1934 in Leningrad the first All-Union Conference on the Study of the Stratosphere, organized by the U.S.S.R. Academy of Sciences, took place. It was conducted by Academician S. I. Vavilov. In 1935

*Translator's note: Expansion not known.

the aviation scientific-technical research society AUASETS called a conference on rocket technology in Moscow. Many workers of the JSRI and other organizations delivered scientific reports at these conferences.

In 1935, on the suggestion of L. K. Korneyev, who worked earlier in the Moscow GSJP, a design group (later the DO-7) was organized for developing liquid-fuel rockets. The work of the DO-7 did not yield the anticipated results, and this organization soon ceased to exist.

The first small two-stage rocket in the U.S.S.R., designed by I. A. Merkulov (a powder first stage and direct-current air-breathing jet engine in the second stage), built by the Jet Section of the Stratosphere Committee of SADACC, on May 15, 1939, started off from a testing field near Moscow.

The collective of specialists on the LRE, which developed in the GL, worked out in the JSRI (1934-1938) a series of experimental engines from the ERE-53 to the ERE-102 for work using nitric acid and tetranitomethane as oxidizers, and the first gas generator, the GG-1, which worked for hours on nitric acid with kerosene and water, producing a neutral pure gas at 580°C and a pressure of 25 atm (passed official tests in 1937).

The ERE-65 engine, which passed official tests in 1936, was the best engine of its time (nitric acid-kerosene fuel, regulated thrust of 50-175 kg, specific impulse of 210-215 sec, manual and automatic launch). The ERE-65 engine withstood many launches: example No. 1 in 50 launches worked 30.7 minutes on the ground, including 20 launches on the stand; on winged missile 212--8 launches, on an RP-318 rocket plane--21 launches; example No. 2 passed through 16 launches, including 5 launches on winged missile 212 and 9 launches on the rocket plane RP-318.

The subdivision organized within the GL on development of electrical and liquid-fuel rocket engines (1929-1933) proceeded /23
on a lengthy and complex path of development from a subdivision of JSRI (1934-1938) to an independent organization (1939-1940), from 1941 on growing into an Experimental Design Bureau (EDB). Such was the creative path of development--from the GL to the twice Order-bearer EDB--of this organization, called by the GL an EDB.

For speeding up the maneuvers of aircraft in the 1940's, this EDB developed a family of auxiliary aviation LRE's with nozzle feeding of nitric acid and kerosene, with chemical ignition, a limited number (within the limits of the engine life) of repeated, completely automatic launches, with regulated thrust and maximum thrust at the ground of from 300 to 900 kg. These

engines, besides the finishing and official stand tests, underwent ground and flight tests in 1943-1946 (about 400 launches) on aircraft designed by V. M. Petlyakov, the Pe-2R; by S. A. Lavochkin, the La-7R and 120R; by A. S. Yakovlev, the Yak-3; and by P. O. Sukhoi, the Su-6 and Su-7.

The following worked as deputy chief engine designers in the EDB at this time: S. P. Korolev (on flight tests in 1942-1946), G. S. Zhiritskiy, D. D. Sevruk, V. A. Vitka, N. N. Artamonov, and others.

The rich experience accumulated in developing this family of LRE's and their aircraft installations served as a foundation on which in the GL-EDE engines for rockets were subsequently built. From 1947-1973 the GL-EDB developed several tens of types of powerful LRE's, which found broad application on rockets for various purposes. These LRE's were installed on the majority of intracontinental and intercontinental Soviet rockets, and also on all the geophysical and space rockets launched up to the present time in the U.S.S.R.

In connection with the 40th anniversary of the GL-EDB (1929-1969) in Leningrad in the buildings of the Chief Admiralty and of the Johannes Ravelin of the Petropavlovsk Fortress, where the GL was located in the 1930's, memorial tablets were installed.

Leningrad is not only the cradle of the revolution, but also the cradle of Russian rocket technology. Here the rockets of Zasyadko, Shil'der, and Konstantinov, using smoke powders, were born, and later the designs of Kibal'chich, Fedorov, the work of Meshcherskiy, Pomorskiy, Rynin, Perel'man, Razumov, (Leningrad GSJP). In this city for the first time the classic works of Tsiolkovskiy were published. Here the Gaseodynamics Laboratory developed its work, which developed the first rockets using smokeless powder, the first electrothermal rocket engine, and the first Soviet liquid-fuel rocket engines, the development of which, executed by the collective which was born in the GL, led to the modern rocket engine with a power of millions of kWh's.

The work of the GL, the GSJP, and the JSRI was a valuable contribution to the history of Russian rocket science and technology.

In the GL--the first organization in the U.S.S.R. for development of rockets and rocket engines--in 1928-1933 rockets were built using smokeless powder charges, in 1929-1933 the first experimental electrothermal rocket engines, the ER, were built /24
and successfully tested, and the first Soviet liquid-fuel rocket engines, the ERE, ERE-1 to ERE-52, which worked on liquid oxygen, nitrogen tetroxide, nitric acid and toluol, benzene and

kerosene. The collective grew out of the GL, continued in the JSRI and later, as an independent organization, developed liquid-fuel rocket engines using various fuels, built the direct descendants of the first ERE's--the powerful engines for the mighty Soviet rocket-carriers of all types which extended a path out into space.

The collective of the GSJP in 1933 launched the first Soviet liquid-fuel 09 rockets using liquid oxygen and hardened benzene and the GSJP-10 using liquid oxygen and alcohol. These were the very first flights, but not so many years had passed when Soviet rockets were the first to penetrate the many millions of kilometers into the depths of the Universe!

In the first Soviet rocket organizations--the GL and the GSJP--the bases of Russian rocket construction were laid. From the halls of the GL and the GSJP the basic cadres emerged which engendered the creative collectives which ensured this development. On May 15, 1969 the twice Order-bearer Experimental Design Bureau marked its 40th anniversary--a path from the GL to our day, from the ERE, with a thrust of several kilograms, to highly perfected rocket engines with a thrust of hundreds of tons.

The GSJP, which also educated a collective of people who made an invaluable contribution to the triumphant achievements of the Soviet Union in the field of the creation of its own rockets and spaceships, also played an enormous role. The scientific-research and experimental-design organizations for developing the most complex flight and ground systems of flight control, the complex of ground equipment, made its creative contribution to the birth and development of rocket-space systems in the U.S.S.R. The synthesis of the work of these collectives and also of many other scientific and industrial collectives which took part in the further development of this work, also lifted Soviet man into space. A decisive role here was played by the high level of industrial development of the Soviet Union, the achievements of advanced Soviet science, and the self-sacrificing labor of the entire Soviet people, led by the Communist Party and its Leninist Central Committee.

STORMING SPACE BY ROCKET SYSTEMS

The planned study of outer space is carried out in the U.S.S.R. with the help of geophysical rockets, vertical space probes, unmanned and piloted satellites of heavenly bodies, and interplanetary stations of the fly-past, fly-around, and landing type.

One may judge the scope of these studies by the fact that by /25
July 1, 1973, in the Soviet Union alone, 742 satellites with a total weight of 2,233 tons or 4,388 tons, considering the weight of the final stages of the rocket-carrier which went out into the same space orbits, had been launched into orbit around the earth, the sun, the moon, and Mars; 41 stations weighing 110 tons (167 tons counting the final stages) were given a speed close to solar system escape velocity.

Since 1949 regular studies have been conducted in the Soviet Union of the upper layers of the atmosphere and space with the aid of geophysical rockets, lifting a payload of scientific apparatus weighing from several tons to 500 km and above. The rocket B2A of this class was used for studying the upper layers of the atmosphere, photographing the solar spectrum, making medical-biological studies and working out a system of lowering (landing) of the nose instrument section weighing 1,340 kg and of geophysical containers weighing 860 kg. The total weight of the payload was 2,200 kg, with a lift of 212 km.

The geophysical rocket B5B was used for astrophysical, geophysical, biological, and ionospheric studies. The weight of the payload was 1,300 kg, the highest lift altitude, 512 km. In rockets of this class a broad program of medical-biological studies was carried out, basically on dogs; in flights into space a parachute system was developed for rescuing animals and apparatus on return to the earth. The rescue was executed both by a smooth lowering of the pressurized cabins and by catapulting from various altitudes with lowering of the rockets and by lowering dogs placed in hermetically-sealed diving suits by parachute.

In the period of the International Geophysical Year, the world was witness to the unprecedented victory of Soviet science and technology. On October 4, 1957, mankind celebrated its first victory over the armor of earth's gravity, when a Soviet rocket first achieved escape velocity and put into orbit around the earth the first artificial satellite. Thus was laid the foundation of the space era in the history of mankind.

The sputnik, weighing 83.6 kg, had an aluminum, sphere-shaped body with a diameter of 580 mm, with four whip aerials from 2.4 to 2.9 meters long. In the pressurized body apparatus and sources for electrical feeding were placed. Signals from the radio transmitters of the satellite on two frequencies, in the form of telegraph messages of an average length of 0.3 sec, announced the first breakthrough into space to the whole world from an altitude as high as 947 km in apogee. The satellite existed as a space body for 92 days, completing 1,400 revolutions around the earth and traversing a path of about 60 million km. For the first time the density of the upper layer of the

atmosphere in respect to the change in the orbit of the satellite was determined, figures were obtained on the distribution of radio signals in the ionosphere, calculations and basic technological solutions connected with the building of the artificial satellite, putting it into orbit, and ensuring its functioning in space, were verified.

A month later, on November 3, 1957, in the U.S.S.R. a second, /26 heavier, and more perfected artificial earth satellite, better equipped with scientific apparatus--the very first biological satellite--was launched. It was the last stage of a rocket-carrier, on which a scientific measuring apparatus had been put in a number of containers; in a separate pressurized cabin an experimental animal--the dog Layka--was placed. The total weight of the apparatus, the animal, and the sources of electrical feeding was 508.3 kg. There were two radio transmitters, a telemetry system, a programmed device, and instruments for studying the radiation of the sun and cosmic rays on the satellite. The systems of regeneration and thermal regulation maintained conditions in the cabin which were necessary for the existence of the animal. The satellite went out into orbit at an altitude of 1,674 km apogee with an inclination of 65.1°. The second satellite stayed in orbit for about 160 days, made 2,370 revolutions around the earth, traversing a path of more than 100 million km.

A third Soviet satellite weighing 1,327 kg, fully supplied with scientific apparatus, put into orbit on May 15, 1958, was a real laboratory in space. On it were set up 12 different scientific instruments, a multichannel telemetry system with a memory device, a radio apparatus for accurate measurements of the orbit, the "Mayak" (beacon) radio receiver, a system of thermal regulation, a programmed-time device, and other flight equipment. The length of the satellite was 3.57 m. The weight of the scientific and measuring apparatus was 968 kg. The height of the apogee reached 1,881 km, the inclination of the plane of the orbit, 65.1°. The satellite remained in orbit for 691 days, flying during this period about 450 million km and making 10,037 revolutions around the planet.

With its help a broad program of studies of the cosmic space around the earth was conducted (measurement of the pressure and composition of the upper atmosphere, of the concentration of charged particles, of cosmic rays, of the magnetic and electrostatic field, of meteor particles, etc.). The measurements made permitted the presence of the external zone of the radiational belt of the earth to be confirmed.

On January 2, 1959, mankind celebrated its second and final victory over the fetters of the earth's gravity when the Soviet scientific space station "Luna-1" attained and exceeded

second cosmic speed, the rocket, weighing 1 1/2 tons, leaving the Earth forever. Flying in indirect proximity to the moon, at a distance of 5,000-6,000 km from its surface, the space station occupied its place in the ring dance of the planets and planetoids revolving around the sun. Thus the first artificial satellite of the sun was created.

This artificial planet, well known in the world press by the name of "Mechta," moves in an orbit with a perihelion of 146.4 million km and an aphelion of 197.2 million km. On the "Luna-1" station radio apparatus, a telemetry system, five different scientific instruments for study of interplanetary space, and other equipment were placed. On the last stage of the rocket an /27
apparatus for creating an artificial comet was also installed.

Another triumph of Soviet science and technology was the reaching of the moon by the unmanned station "Luna-2" on September 14, 1959. For the first time a creation of human hands crossed the endlessness of space and reached the heavenly body nearest to us. The time will come when brave astronauts will find in the region of Archimedes' Crater in the Gulf of Lunnik the spherical and ribbon banners of the Country of the Soviets, left by the "Luna-2" station.

Twenty days after the rocket reached the surface of the moon, the unmanned station "Luna-3" with a weight of 278.5 kg was launched, for the first time completing a flight around the moon, photographing its far side, which is invisible from the earth, and transmitting the reflections received to ground radio stations. Thus fell still another veil from the secrets of the universe.

"Luna-3" passed the surface of the moon at a distance of 6,200 km. The flight was the first experiment in the study of another heavenly body from onboard a space apparatus.

As a result of laborious work over a period of many months in deciphering and studying recordings of the televised images, 498 formations on the lunar surface were revealed and described, including 400 invisible from the earth, their selenographic coordinates were established, and a map and an atlas of the far side of the moon were composed and published by the U.S.S.R. Academy of Sciences in 1960. Some newly discovered lunar formations were given names by the Commission of the U.S.S.R. Academy of Sciences. Thus there appeared the Sea of Moscow with the Gulf of the Astronauts, the Sea of Dreams, the Tsiolkovskiy, Lomonosov, Lobachevskiy, Jules Verne, Giordano Bruno, Maxwell, Popov, Edison, Pasteur, Hertz, Joliot-Curie, Mendeleyev, Kurchatov and other craters.

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The studies of near space and of space around the moon, conducted by the three unmanned stations "Luna-1," Luna-2" and "Luna-3" also yielded very valuable material; in particular, they established the fact that there is no significant magnetic field or radiation belt around the moon.

Work was done on a complex of problems connected with ensuring the soft landing of an unmanned station on the surface of the moon in order to study the moon in the future. For this purpose, a new, more powerful multistage rocket-carrier was built.

Flights of the "Luna-1," "Luna-2," and "Luna-3" stations from the earth were achieved by constant selection of the required speed and subsequent flight to the target by inertia (direct flight). The routes of the subsequent stations were executed according to a more complex scheme: The station was put into an earth satellite orbit by a rocket-carrier, the launch from this orbit in the prescribed moment of time and gaining of speed close to second cosmic speed, the correction of the trajectory in approach flight to the moon, reduction of speed by a braking engine device, and ensuring of a soft landing on the moon.

The difficulty of the task required lengthy development. In 1963-1965 for further study of the moon and resolution of the problem of soft landing of a container with scientific apparatus on the lunar surface, the "Luna-4" to "Luna-8" stations were launched. "Luna-5" reached the surface of the moon on May 12, 1965, and the first experimental data on the work of the systems for soft landing were obtained; "Luna-6" passed near the moon on June 11, 1965. "Luna-7" reached the surface of the moon on October 8, 1965, and "Luna-8" on December 7, 1965. /28

The automatic station "Luna-9" which set off on January 31, 1966, for the first time on February 3 accomplished a soft landing on the surface of the moon in the Gulf of Moon Landing of the Ocean of Storms. The soft moon landing station, weighing 100 kg, transmitted to the earth phototelevision images of the lunar surface and various telemetric information. Thus for the first time circular panoramic photographs of the lunar landscape were obtained, which permitted an object measuring 1-2 mm in direct proximity to the station to be distinguished. On board this station a banner and state coat of arms of the U.S.S.R. were again delivered to the moon.

As a result of this unprecedented space experiment, the hypothesis of a more or less thick dust cover on the surface of the moon was refuted. The lunar soil turned out to be rather hard, uneven, covered with stones and craters of various

dimensions, scattered about--from tiny holes to large formations. The radiation situation was also studied.

The next triumph of the Soviet Union was the launching, on April 3, 1966, of the unmanned station "Luna-10" into the first artificial moon satellite orbit. On this station, weighing 245 kg (not counting the weight of the system for putting it into selenocentric orbit), scientific apparatus was installed for determining the radiational and meteor situation, the infrared and gamma radiation of the lunar surface, the composition of lunar rocks, the magnetic field of the moon, solar plasma in space near the moon, and the gravitational field of the moon. The radio stations of the world received the melody of the Party hymn of the Communists, "The Internationale," beamed from on board the "Luna-10" station, which circled the moon at a distance of 350 km (in periselenion) to 1,017 km (in aposelenion) with an orbital inclination of 71°54'.

In 1966 two more stations, "Luna-11" and "Luna-12," were put into an artificial moon satellite orbit, equipped with various scientific apparatus. Over the course of several months, the stations conducted a number of valuable scientific studies, and "Luna-12," which had on board a phototelevision system with high resolution (1,100 lines), transmitted to the earth a series of photographs of the lunar surface, taken from altitudes of from 100 to 340 km.

On December 24, 1966, another Soviet unmanned station--"Luna-13"--made a soft landing on the moon. The studies made by the station in the Ocean of Storms enriched science with new data on the properties of lunar soil. The density of the soil turned out to be no greater than 1 g/cm^3. Television images of the panorama of the moon's surface under various degrees of solar illumination were again obtained.

The fourth Soviet artificial moon satellite--"Luna-14"--was launched on April 7, 1968. The altitude of its periselenion was 160 km, the aposelenion--870 km, the inclination--42°, period of revolution--2 hours, 40 min. With the help of "Luna-14" the following were planned: a clarification of the relationship of the masses of the earth and the moon and of the gravitational field of the moon, conditions for the occurrence and stability of radio signals transmitted to the satellite in various positions relative to the moon, measurement of cosmic rays and streams of charged particles coming from the sun, and the obtaining of additional information for constructing an exact theory of the movement of the moon. /29

On July 13, 1969 the first Soviet satellite of the moon--"Luna-15"--was launched. After it went out into selenocentric orbit, two corrections of orbit were made, and as a result the satellite was lowered to an altitude of 16 km over the surface of the moon. With the help of "Luna-15" scientific studies on space near the moon were made and data were obtained on the work of the new systems of the station, ensuring possible landing in various regions of the lunar surface. After completing 52 revolutions around the moon, "Luna-15" reached its surface.

A brilliant example of the possibilities of robot stations in the study of other heavenly bodies was "Luna-16," which for the first time delivered lunar soil to the earth. The station started from the earth on September 12, 1970, and on September 20 made a soft landing on the surface of the moon in the region of the Sea of Abundance. On radio commands from the earth a soil-gathering device performed the taking of soil and loading it into the container of the returning apparatus. On September 21 the space rocket "Moon-Earth" started from the landing stage to the earth. On September 24, 1970, on the approach flight to the earth, the returning apparatus was separated from the rocket and with the help of a parachute system landed in the region of the city of Dzhezkazgan. More than 100 g of lunar rock underwent various studies in laboratories and was shown at exhibits.

Developing a fruitful and economical method of study of space and heavenly bodies by unmanned devices, the Soviet Union with the help of station "Luna-17" for the first time delivered to the surface of the moon an automated self-propelling machine, the "Lunokhod-1," radio controlled by operators on earth with the help of television. The station started on November 10, 1970, went off, as the two previous stations, at first into geocentric, and then into selenocentric orbit, and on November 17 made a soft landing on the surface of the moon in the Sea of Rains. On the same day "Lunokhod-1" descended by ramps from the landing stage of the station and began scientific and technical studies at various distances from the landing spot. "Lunokhod-1," with an eight-wheel landing gear, with an individual electrical engine on each wheel fed by electrical energy from solar batteries, displayed good maneuverability, going over or around obstacles.

Supplied with an isotropic source of heat, "Lunokhod-1" functioned for a period of 322 days (11/17/1970-10/4/1971), traversing the surface of the moon along a prescribed route of 10,540 m and making a detailed topographical study of 80,000 m^2 of the moon's surface. During this time 171 communications broadcasts were made, and 24,829 commands were transmitted on board through radio channels. With the help of the radiotelevision systems of "Lunokhod-1," 206 panoramas and more than 20,000 photographs of the moon's surface were transmitted to the earth. The

/30

physical-mechanical properties of the surface layer of soil were studied at more than 500 points, and in 25 places a chemical analysis was conducted. Results were obtained of experiments with an X-ray telescope installed on "Lunokhod-1," with a radiometric apparatus, and a French angular laser reflector. This experiment was continued with the aid of the "Luna-21" station which on January 16, 1973, conveyed to the eastern edge of the Sea of Clarity "Lunokhod-2," which differs from "Lunokhod-1" in its additional equipment and improved traveling qualities. In five lunar days "Lunokhod-2" covered 37 km under conditions of a rough relief.

"Luna-18," which started on September 2, 1971, went into a lunar satellite orbit and made 54 revolutions but the attempt to make a landing in the region of the continent surrounding the Sea of Abundance was unsuccessful. On September 28 of the same year "Luna-19" was launched, with the goal of conducting scientific experiments from an artificial moon satellite orbit.

"Luna-20," sent on February 14, 1972, made a soft landing on the moon in the sector of the continent adjacent to the Sea of Abundance, drilled the soil, collected samples of lunar rock, and brought them back to earth. Some of the samples of lunar soil brought to earth by the "Luna-16" and "Luna-20" automatic stations were transmitted for analysis to France, England, the G.D.R., and other countries. The U.S.S.R. and the U.S.A. have exchanged samples of lunar rocks.

An outstanding achievement is the high-quality photography of the far side of the moon, executed on July 20, 1965, and Soviet automatic station "Zond-3," at a distance of about 10,000 km. Two-thirds of the surface of the moon invisible from earth was photographed, primarily the regions not photographed by the "Luna-3" station in 1959. As a result, only 5% of the lunar surface was still unphotographed.

As a result of the studies of photographs of the far side of the moon, taken by stations "Luna-3" (1959) and "Zond-3" (1965), the P. K. Shternberg State Astronomy Institute (SSAI), together with a number of other organizations under the scientific leadership of Doctor of Physical-Mathematical Sciences Yu. N. Lipskiy, published an Atlas of the Far Side of the Moon (1st part--1960, 2nd part--1967), with a catalogue of about 4,000 formations which had been discovered for the first time. A Commission of the Academy of Sciences of the U.S.S.R. on naming the formations on the far side of the moon, with the rights of discoverers, in 1960, 1966, 1967, and 1968 gave to a large part of the discovered formations the names of Soviet and foreign scientists, including names connected with cosmonautics and rocket construction. In

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addition to the names of craters adopted in 1960 there appeared: Zasyadko, Konstantinov, Kibal'chich, Gansvindt, Meshcherskiy, Fedorov (A. P.), Tikhomirov, Pomortsev, Artem'yev, Perel'man, Kondratyuk, Tsander, Vetchinkin, Grave (D. A.), Rynin, Petropavlovskiy, Langemak, Korolev, Razumov, Il'in, Kleimenov, Bakhchivandzhi, Vasil'chenko, Rastorguyev, Konoplev, Voskresenskiy, Gagarin, Komarov, and others. Several lunar craters were given the names of workers of the GL-EDB: Malyy, Petrov, Chernyshev, Zhiritskiy, Artamonov, Gavrilov, Firsov, Alekhin, Grachev, and Mezentsev. /31

Lunar craters were also given the legendary names of Icarus and Dedalus, Van Gogh, the writers Cyrano de Bergerac, Ero and Wells.

In consideration of the ground-breaking contribution of the GL, GSJP, and JSRI in the development of Russian rocket construction, the newly discovered collective formations on the far side of the moon--the crater chains--were given the names of these organizations. Thus, the crater chains 520 and 540 km long were named GSJP and JRSI, respectively. The Commission gave the name of Lunnik Gulf to the region of the first hard landing ("Luna-2") and the name of the Gulf of Priluneniye to the region of the first soft landing on the lunar surface ("Luna-9").

The International Astronomical Union in 1970 confirmed the majority of these names. Additionally presented materials should allow this organization to confirm the remaining several names, connected with the creation and development of rocket construction and cosmonautics in the U.S.S.R.

In 1966-1967, according to materials of the Atlas of the Far Side of the Moon and the well-known photographs of the surface of the moon visible from the earth, the SSAI and the Topogeodesic Service of the U.S.S.R., under the seientific leadership of Yu. N. Lipskiy, composed and published the first complete map of the moon (1:5,000,000) and complete globe of the moon (1:10,000,000), and in 1968 published an atlas consisting of 7 maps of the equatorial zone of the visible hemisphere of the moon (1:1,000,000). Later in the U.S.A. and the U.S.S.R. complete maps and globes of the moon were published, composed with the aid of the photographs by "Zond-3" and "Lunar Orbiter."

"Zond" is the name of a series of Soviet unmanned interplanetary stations launched since 1964 and designed for the study of cosmic space and working out a technology for distant space flights. "Zond-1" to "Zond-3" each had a weight of about 950 kg, and were supplied with a system of astroorientation (according to the sun, the earth, and the star Canopus) and a correcting engine device. Energy supply of the flight apparatus was provided by solar batteries. The station's thermoregulation system was

calculated for work at various distances from the sun. The launching of the last stage of the rocket-carrier from the station was done from an intermediate geocentric orbit.

"Zond-1," launched on April 2, 1964, went into heliocentric orbit. "Zond-2," launched on November 30, 1964, in the direction of the planet Mars, for the first time had on board 6 electric-jet plasma engines, which served as executing organs for the system of orientation.

"Zond-3" was launched on July 18, 1965, in the direction of the moon. On board, besides scientific apparatus, was a photo-television system with automatic processing of the tape on board, which possessed a high resolving power (number of strokes per television transmission was 1,100, possible range of transmission of images up to hundreds of millions of km). During the flight of the station past the moon, 25 photographs of the far side of the moon were obtained at a distance of 11,570-9,960 km, embracing 19 million km^2 of the lunar surface, including more than 10 million km^2 which were not included in the scope of the far side of the moon by station "Luna-3." /32

The transmission of images to earth was done at a distance of 2.2 million km, and the second transmissions from a distance of up to 31.5 million km. After flying past near the moon, "Zond-3" continued the study of cosmic space, moving in a heliocentric orbit.

The subsequent stations--"Zond-4" to "Zond-8"--were sent into orbit by a more powerful rocket-carrier and had the goal of making a flight design test in the automated variation of the ship for flying around the moon, making scientific studies and returning to the earth at second cosmic speed. The last stage of the rocket-carrier with the station started from an intermediate geocentric orbit.

The spaceship station has a descent apparatus with a heat-reflecting covering, an instrument section with the basic flight systems (radio communications, telemetry, orientation and stabilization, energy supply, thermal regulation) and a corrective engine installation. The system of orientation is active, has optical sensors (sun and earth) and a system of controlling engines of low thrust. The energy supply of the flight apparatus is from solar batteries, which are opened in flight. In the descent apparatus are located scientific apparatus, photo apparatus, radio and telemetry apparatus, a system of control of the descent, and a parachute system.

"Zond-4," which was launched on March 2, 1968, went into heliocentric orbit. On September 18,1968, "Zond-5" made a flight

around the moon at the minimal distance from its surface of 1,950 km and photographed the earth from a distance of 90,000 km. In approach flight toward the earth a correction of trajectory was made, which ensured the descent of the station into the re-entry corridor. On September 21, the descent apparatus entered the atmosphere of the earth and made a descent on a ballistic trajectory, landing in the Indian Ocean.

In this flight for the first time a space vehicle returned to the earth at second cosmic speed after orbiting the moon. On "Zond-5", the first flight around the moon and return to earth by living terrestrial beings, turtles, was made.

"Zond-6" was launched on November 10, 1968. The program of flight planned a flight around the moon, scientific studies, and return to earth, this time by making a controlled descent. On November 14, "Zond-6" flew around the moon at a minimal distance of 2,420 km from its surface and near the moon made complex scientific investigations, including photographing it from distances of about 11,000 km and 3,300 km. In flight toward the earth corrections of trajectory were made, which ensured an exact descent into the re-entry corridor. The trajectory of descent had a length of about 9,000 km and consisted of a section of first plunge (in which the speed was reduced to 7.6 km/sec), a section of extra-atmospheric flight on a ballistic trajectory and a section of second plunge, in which occurs the basic braking of the apparatus to a speed of about 200 m/sec. The control of movement on the trajectory of descent was achieved by regulating the size of the lift force by turning the descent apparatus in a bank. On November 17 the descent apparatus landed in the prescribed region of the Soviet Union. /33

The scheme and program of flight of "Zond-7," launched on August 8, 1969, were the same as those of "Zond-6." On August 11 "Zond-7" flew around the moon and on August 14 landed south of the city of Kustanay, having executed a program and brought to earth color photographs of the moon and the earth from various distances. On "Zond-5 to Zond-7" broad biological experiments were conducted. The passengers of these stations were turtles.

Finally, "Zond-8" flew around the moon on October 24, 1970, at a distance of 1,120 km from its surface. In the high mountain observatory of the Shternberg State Astronomical Institute in the mountains of Ziliyskiy Alatau, with the aid of opticophototelevision apparatus, a picture was taken of "Zond-8" from a distance of 348,000 km. The descent apparatus landed on October 27 in the Indian Ocean in the prescribed region--730 km southeast of the Chagos Archipelago. In this flight a variation of the return to earth from the direction of the northern hemisphere was tried out.

Simultaneously with the study of the moon, from in the U.S.S.R. flights of unmanned stations are being made to the nearest planets--Venus and Mars.

Flights of unmanned stations with scientific apparatus to Venus were begun on February 12, 1961, when for the first time from on board a heavy (6.5 ton) artificial earth satellite--the station "Venus-1"--was launched, with a weight of 643.5 kg. This station on May 19-20, 1961, passed at a distance of less than 100,000 km from Venus, covering a path of 270 million km. Thus was born the second Soviet artificial satellite of the Sun.

"Venus-2," which started on November 12, 1965, weighing 963 kg, passed on February 27, 1966 at a distance of 24,000 km from the surface of Venus, and then went into heliocentric orbit.

"Venus-3," which was launched on November 16, 1965, had a weight of 960 kg. The spherical apparatus--with a diameter of 900 mm--dropped onto Venus has a covering resistant to the heat from braking in the Venerian atmosphere, and a landing parachute. In flight 63 radio communications were made and a correction of trajectory was executed, ensuring the landing of the station on the planet. On March 1, 1966, after 3½ months of flight, the station for the first time ever reached Venus and delivered onto its surface a spherical pennant with the coat of arms of the U.S.S.R.

In flight toward the planet, radio communications were lost with these stations, which prevented completion of the program of experiments.

On June 12, 1967, the "Venus-4" station, weighing 1,106 kg, /34 was launched. In flight 114 radio broadcasts were made, transmitting scientific information. At a distance of 12 million km from earth a correction of trajectory was made for landing on the planet. On October 18, 1967, passing at a distance of about 350 million km, the station penetrated at second cosmic speed the atmosphere of Venus and the descent apparatus with 2 radio transmitters of decimeter range, a telemetry system, scientific apparatus, a radio altimeter, a system of thermal regulation, and sources of electrical supply, separated from it. After aerodynamic braking of the apparatus, the speed was reduced from 10.7 km/sec to 300 m/sec, and then the parachute system began operation; the instruments, during 1½ hours of descent by parachute on the night side of the planet, measured the pressure, density, temperature, and chemical composition of the atmosphere of Venus. The descent apparatus, weighing 383 kg, brought onto the surface of Venus a second pennant depicting the coat of arms of the Soviet Union. The station, launched from the earth, made for the first time a smooth descent in the atmosphere of another planet

and transmitted data about the characteristics of the atmosphere of Venus in a range of pressures of 0.5-18 atmospheres.

"Venus-5" was launched on January 5, and "Venus-6" on January 10, 1969. Both stations, weighing 1,130 kg apiece, were supplied with simplified descent apparatuses weighing 4,051 kg apiece, and with a wide range of scientific and measuring apparatus for continuation of investigations of the interplanetary environment and the atmosphere of Venus. In the descent apparatuses there were pennants with a picture of the coat of arms of the Soviet Union and a bas-relief of V. I. Lenin. In flight, regular radio broadcasts were made and scientific information was received. After making a correction of trajectories at a distance of 15.5-15.7 million km from the earth, the stations reached Venus on May 16 and 17, 1969, the descent apparatus with the scientific apparatus automatically separated from the stations and as a result of aerodynamic braking in the atmosphere of the planet, their speed was reduced from 11.17 km/sec to 210 m/sec; then the parachute systems were put into operation and the descent apparatus made a smooth descent in the atmosphere in 51-53 minutes on the night side of the planet. The joint flight of the stations ensured a great volume of information, including exact data on the atmosphere of Venus in a pressure range of 0.5-2.7 atm, i.e., down to layers of the atmosphere deeper than in the flight of "Venus-4."

"Venus-7," which was launched on August 17, 1970, reached the planet Venus on December 15 of the same year. During the flight of this automatic station, weighting 1,180 kg, 124 radio broadcasts were made from it. After separation and aerodynamic braking, the additionally simplified descent apparatus began descent by parachute, transmitting radio signals over a period of 35 minutes, and for the first time made a soft landing on Venus, making valuable scientific measurements right down to its surface, on which the pressure of the atmosphere turned out to be equal to about 90 atm and the temperature around 470°C.

"Venus-8," after a four-month flight (started March 27, 1972), after covering a path of more than 300 million km, reached the planet on July 22, 1972. The descent apparatus of the station made for the first time a smooth descent in the atmosphere on the illuminated side of Venus and made a soft landing on its surface. With descent of the apparatus in the atmosphere and during the course of 50 minutes of its work on the scorching surface of Venus, valuable scientific information was transmitted to the earth on the properties of the atmosphere on the day side of the planet (illumination, temperature, pressure) and on the character of the rocks of its surface layer. /35

Making its flight in the year of the 50th anniversary of the creation of the U.S.S.R., the station brought to the planet

pennants with a bas-relief of the founder of the Soviet state, Vladimir Il'ich Lenin, and the state coat of arms of the U.S.S.R.

The beginning of flights to Mars was made by the Soviet unmanned scientific station "Mars-1," weighing 893.5 kg, which started on November 1, 1962. Bilateral radio contact with the station was achieved during 61 broadcasts at distances of up to 106 million km. Transmitting valuable information about the condition of the environment on the interplanetary route, the station flew around Mars on June 19, 1963, and went into heliocentric orbit with a perihelion of about 148 million km and an aphelion of about 250 million km.

"Mars-2," weighing 4,650 kg, was launched on May 19, 1971, and in the course of 192 days covered a path of 470 million km to the red planet. For the first time the surface of Mars was reached by the descent apparatus of this unmanned station, which went into an artificial Mars satelliite orbit on November 27, 1971. The "Mars-3" station, with the same weight, began flight on May 28, and on December 2, 1971, its descent apparatus entered the atmosphere of the planet, made a descent by parachute and for the first time made a soft landing on the surface of Mars. With this the station went into an artificial Mars satellite orbit. The landing was made in the southern hemisphere of Mars between the regions of Elektris and Faetontis. Signals from the apparatus which completed the landing were transmitted to earth through the satellite "Mars-3," but soon ceased.

The study of the atmosphere, the surface of Mars and the space around the planet with the help of phototelevision and a complex of scientific apparatus installed on the artificial satellites "Mars-2" and "Mars-3" greatly enriched science.

Together with the development of unmanned interplanetary stations in the U.S.S.R., work was actively carried out on the creation of heavy piloted satellite-airships which could return to earth, and of a powerful rocket-carrier necessary for this. At first these were automatically controlled satellite airships, supplied with various apparatus and systems, carrying on board up to two experimental animals--dogs and various numerous biological objects, and also a mannequin of a cosmonaut.

From May 15, 1960, through March 25, 1961, five such satellite-airships were sent into orbit around the earth, each weighing 4,540-4,700 kg. In the descent of the satellite-ship, a /36
container with dogs--Belka, Strelka, Chernushka, Zvezdochka,--and other items was catapulted from it, and descended by parachute in the prescribed region onto dry ground.

In sum, the design of a flying apparatus for the flight of man into space was created and all the numerous and necessary systems were developed; for example, for life support and the safety of the cosmonaut in the cabin, for multichannel radio communications, trajectory changes, television and telemetry information, systems for stabilization and orientation of the cosmonaut's cabin, a braking engine device, and for soft landing.

The crowning achievement of Soviet space-rocket construction is the first flight into space of the satellite-ship "Vostok" with a man on board on April 12, 1961. The pilot-cosmonaut of the satellite-ship "Vostok" was the citizen of the Union of Soviet Socialist Republics Major Yuriy Alekseyevich Gagarin. After flying around the earth in an elliptical orbit and completely fulfilling the prescribed program, the cosmonaut, at the beginning of the second spiral, landed with the ship "Vostok" without mishap in the prescribed region of the Soviet Union. In memory of the outstanding event, an obelisk has been placed on the landing spot--near the village of Smelovka, Ternovskiy raion, Saratov Oblast'.

In celebration of the first flight of Soviet man into space, by Decree of the Presidium of the U.S.S.R. Supreme Soviet, Cosmonaut's Day was established, to be celebrated annually on April 12.

By resolution of the International Aviation Federation (IAF), April 12 is World Aviation and Cosmonautics Day, celebrated annually since 1968.

A new era in the history of mankind began, an era of the direct penetration by man into space. Crews of one, two and three cosmonauts on eight Soviet spaceships of the "Vostok" and "Voskhod" systems went into artificial earth satellite orbits in 1961-1965.

The names of these eleven Soviet hero pilot-cosmonauts, each of whom made a new contribution to the conquest of near space, will remain forever in history.

Yu. A. Gagarin was the first man who freed himself from the power of the earth's gravity and made a complete flight around the planet in a cosmic orbit at an altitude of up to 327 km.

G. S. Titov for the first time flew for days at escape velocity around the earth on the ship "Vostok-2," which was launched on August 6, 1961.

A. G. Nikolayev--the first to roam near space for four days in the ship "Vostok-3," which was sent into orbit on August 11,

1962. P. R. Popovich--who flew for three days on the ship "Vostok-4" in the first group flight with A. G. Nikolayev. In the flight, radio communication was maintained between the spaceships and the earth. Television broadcasts of the cosmonauts were transmitted for the first time by the television network of the U.S.S.R. and intervision, and thereby cosmovision was begun.

V. F. Bykovskiy--for the first time lived and worked for five days (June 14-19, 1963) on the ship "Vostok-5" among the stars, in the vastness of space. /37

V. V. Tereshkova--the first woman cosmonaut, who flew for three days on the ship "Vostok-6" (June 16-19, 1963) in group flight with V. F. Bykovskiy.

V. M. Komarov, K. P. Feoktistov, and B. B. Yegorov--the famed crew of the three-passenger spaceship "Voskhod," which consisted of a pilot-cosmonaut and two scientist-cosmonauts (for the first time without flight suits), which for days made the most valuable experiments at altitudes of up to 408 km in an earth satellite orbit (October 12-13, 1964).

P. I. Belyayev and A. A. Leonov were the crew of the first two-passenger spaceship, "Voskhod-2," which during orbital flight at an altitude of up to 498 km for the first time made an invaluable experiment with a space walk by man (March 18-19, 1965). The spacewalk was performed by A. A. Leonov through a lock in a pressure suit with an autonomous life-support system, at a distance from the ship of up to 5 m. Although the period outside of the ship lasted only 20 minutes (outside of the lock--12 min), it was proven that man can exist and work outside a spaceship, protected only by a flexible suit. The process of the space walk and the time A. A. Leonov spent outside the spaceship were photographed by movie cameras installed within the ship and in the lock section. The landing of "Voskhod-2" on earth was done by a manual system of control.

In conquering virgin territory in space, each of these eleven Soviet cosmonants executed for the first time new assignments which had no precedents, but they created precedents for others.

The center for training of cosmonauts in Star City brilliantly managed the difficult and responsible task entrusted to it. The satellite spaceships "Vostok" created for the cosmonauts, weighing 4.7 tons, and the "Voskhod," weighing 5.3 tons, were well controlled and obeyed the experienced hands of their pilots.

The "Vostok" ship has a spherical descent apparatus, which is at the same time the cabin of the cosmonaut, and an instrument section with flight apparatus and a braking engine device designed by A. M. Isayev. The weight of the ship with the last stage of the rocket-carrier is 6.17 tons, the length is 7.35 m, the weight without the last stage is 4.73 tons, the weight of the descent apparatus is 2.4 tons, and its diameter is 2.3 m. The cosmonaut in a space suit, is placed in an ejection seat; control of the ship is effected automatically and also by the cosmonaut. The life-support system is calculated to last for 10 days; in-flight radio communication is constantly maintained with the earth. A braking engine device is included for landing of the ship, lowering its speed to transition to the trajectory of descent, when the descent apparatus separates; after braking of the descent apparatus in the atmosphere, the cosmonaut catapults out of the cabin at an altitude of 7 km and lands by parachute.

In design and equipment, the multiseat "Voskhod" ship differed from the ships of the "Vostok" series; it was supplied with a system for soft landing, had a reserve braking engine device, new instrument equipment (an additional system of orientation with ion sensors, improved television and radiotechnical apparatus, etc.). /38

The launching of unmanned artificial satellites, interplanetary stations, and piloted ships into cosmic orbits was made in the U.S.S.R. by powerful, continually improved rocket-carriers.

In 1957 the whole world learned about the successful flights in the Soviet Union of the first intercontinental rocket in the world. The use of this rocket was peaceful, directed for the welfare of mankind. It was this very two-stage, five-engine rocket which launched into orbit in 1957-1958 the first three artificial earth satellites, which astonished the world.

More powerful three-stage rocket-carriers 38 m high and with a maximum diameter along the stabilizers of 10.3 m launched into near space the famous "Vostok" family of satellite-ships. This rocket uses oxygen-kerosene fuel and has a lengthwise division of one and two stages and a crosswise division for two and three stages. Stage 1 consists of four lateral blocks 19 m in length and with a diameter of up to 3 m, with an RE-107 engine on each of the units. Stage 2 is the central unit of the rocket, 28 m long, with a diameter of up to 2.95 m with an RE-108 engine. The length and diameter of stage 3 are 10 and 2.58 m respectively. The unit of stage 3 has a one-chamber rocket engine with 4 rudder nozzles. Six-engine devices of this rocket develop a total maximum thrust by stages, equal to 600 tons, and a total maximum useful power in flight by stages of 20,000,000 Hp.

A determining factor in making flights in space is the level of development of rocket engines and the construction characteristics of the rocket. The speed acquired by the rocket in the first place is determined by the energy characteristics of its engine.

A basic indicator of the perfection and efficiency of a rocket engine is its specific impulse. The specific impulse in a vacuum of an RE-107 engine, flying more than 15 years, is 314 sec with a thurst of 102 tons. The swinging rudder chambers, fed by the general turbo-pumping system, reduce the specific impulse by only 1 sec.

Substantially higher characteristics are possessed by the rocket engines developed in the U.S.S.R. in recent years. The high specific impulse of the engines installed on Soviet rocket-carriers allowed a realization of enormous power with relatively moderate fuel consumption. The creation of such engines is one of the chief achievements which ensure the success of the Soviet Union in the mastery of space. /39

The combination of the high degree of perfection in the design of engines, control systems, and the complex of ground starting equipment allowed the creation of a rocket-carrier with great possibilities and its wide use for the conquest of space. A booster rocket-carrier was used for putting the "Voskhod" and "Soyuz" ships into space. More complex four-stage modifications of a rocket carrier of the "Vostok" type put into space orbits the unmanned stations "Luna-1"; "Mars-14", and "Venus-1".

While engines installed on the first stages of all the rocket-carriers and the second stages of the majority of them were developed by the GL-EDB, the chief engines installed on unmanned interplanetary stations and piloted spaceships were developed by A. M. Isayev and the design bureau which he led.

A. M. Isayev (1908-1971), who since 1958 had worked in the aircraft industry, and who was one of the creators of the BI-1 aircraft, in 1942 occupied himself with developing liquid-fuel rocket engines, and from 1944 on headed an experimental design bureau which created a whole series of engines for rocket and space technical equipment. A. M. Isayev was among the first builders of rocket engines.

The engines for the upper stages of many rocket-carriers were developed by S. A. Kosberg (1903-1965), who began to work on LRE's in 1954.

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In the mastery of space a significant place belongs to S. P. Korolev (1906-1966)--an outstanding designer of the first spaceships, intercontinental and space rockets. These rockets were developed by him jointly with the chief designers of engines, control systems, complexes of ground equipment, and other flight and ground systems.

As a result of the joint labor of the experimental design bureaus which they led, in cooperation with a number of scientific research institutes of industry and of the U.S.S.R. Academy of Sciences, numerous examples of rocket-space technology were developed and introduced into production.

On the massive gold tablet Tsiolkovskiy medal, presented by the Academy of Sciences of the U.S.S.R., there is engraved: "For outstanding work in the field of interplanetary communications." In 1958 the first medal was awarded to the chief designer of rockets and spaceships, the second to the chief designer of rocket engines, and the third to the chief designer of a control system for rockets. Tsiolkovsky medals were also awarded to /40
cosmonauts and to the theoretician of cosmonautics, M. V. Keldysh, for his outstanding contribution to the scientific development of problems of the study and mastery of space.

The rocket-space systems, the development of which was headed by S. P. Korolev, permitted the first launching of artificial satellites of the earth and sun, flights of the first eleven Soviet cosmonauts on the satellite-ships "Vostok" and "Voskhod," and also the flights of the first unmanned stations to the moon, Venus, and Mars, and the making of a soft landing on the surface of the moon. Under Korolev's leadership, artificial earth satellites of the "Electron," "Molniya-1," and many satellites of the "Kosmos" series, and the first examples of the interplanetary scouts of the "Zond" series, were created.

The national development of rocket and space endeavors brought to life more than 15 years ago new collectives, headed by other chief designers of rockets and spaceships, engines, control systems, and starter systems. This not only increased the power of the Soviet scientific and technical base in the rocket-space field, but also allowed it to embrace more objectively several different trends in the development of rocket systems and to critically choose paths for the optimum solutions of problems. They created a number of marvelous intercontinental rockets, rocket-carriers, and space objects. Thus there appeared the numerous satellites of the "Kosmos" series, robots on the moon and satellites of the moon "Luna-15"—"Luna-21," and also the interplanetary stations "Venus-2"—"Venus-8," "Mars-2"—"Mars-3," the maneuverable unmanned "Polet" ships, the powerful "Proton" rocket-space system, and many other developments.

M. K. Yangel' (1911-1971) was one of the outstanding designer-builders of Soviet rocket-space technical equipment. The collective which he evolved jointly with the collectives led by other chief designers--of engines, control systems, and starting complexes--made an invaluable contribution to the development of rocket-space technology and the study of space around the earth.

G. N. Babakin (1914-1971)--an outstanding designer and scientist in the field of space technology--continued the development begun by S. P. Korolev, and created a number of unmanned space apparatuses for study of the moon and the planets.

Especially varied were the scientific space stations of various types and purposes in the "Kosmos" series, which have been regularly launched into various earth satellite orbits since March 16, 1962. For execution of the broad program planned for this series, several types of two-, three-, and four-stage rocket-carriers of various cargo capacities (from several hundreds of kg to tens of tons) were launched from several cosmodromes of the Soviet Union.

The first representative of this series of rocket-carriers is the two-stage "Kosmos" rocket, 30 m long, with a diameter of 1.65 m, successfully flying since March 16, 1962. Since October 14, 1969, this same rocket-carrier has been launching into earth satellite orbits the "Interkosmos" series. The first stage is /41
equipped with an RE-214 engine with a thrust of 74 tons, working on a nitric-acid oxidizer and carbon fuel. The last stage is equipped with an RE-119 engine with a thrust of 11 tons, working on a propellant of liquid oxygen and non-symmetrical dimethylhydrazine. The artificial earth satellite is placed on the last stage under the nose fairing, which is thrown off in the launching stage after passing through the dense layers of the atmosphere. At the end of the launching stage, the satellite is separated from the last stage.

The RE-214 engine has the greatest thrust and specific impulse (in a vacuum, 264 sec) among the well-known engines of this class working on nitric acid oxidizer and carbon fuel. This engine was installed and has been flying since 1957 on the prototype rocket "Kosmos" and is related to early developments of the GL-EDB (1952-1957).

The RE-119 engine of the second stage of this rocket, developed in the GL-EDB in 1958-1962, was produced, basically, of titanium, uses the basic fuel in a one-component gas generator and possesses the highest specific impulse in a vacuum--352 sec--among the oxygen rocket engines using high-boiling-point fuel.

In the "Kosmos" program, from March 16, 1962 through July 1, 1973, 576 scientific stations were launched into earth satellite orbits.

The broad program of scientific studies executed with the help of the satellites of the "Kosmos" series chiefly plans the study of tne external layers of the atmosphere, of space around the earth, and also the testing of many elements of the design of space apparatuses. Significant attention has also been devoted to medical-biological studies. The scientific program plans to study the concentration of charged particles, corpusculary currents, the distribution of radio waves, the radiation belt of the earth, cosmic rays, the magnetic field of the earth, the sun, meteorite substance, cloud systems in the atmosphere of the earth, the influence of the factors of space, the resolution of technical problems connected with space flights (docking in orbit, entrance of space flying vehicles into the atmosphere, orientation in space, life support, protection against radiation), and also testing of many elements of the design of flight systems of space apparatuses.

The orbits of the "Kosmos" satellites include a range of altitudes from approximately 145 km to 60,600 km ("Kosmos-260"); some of these satellites were launched simultaneously by one rocket-carrier, for example, "Kosmos-38"--"Kosmos-40." "Kosmos-71"--"Kosmos-75," "Kosmos-336"--"Kosmos-343," "Kosmos-411"--"Kosmos-418," "Kosmos-444"--"Kosmos-451." "Kosmos-504"--"Kosmos-511," "Kosmos-528"--"Kosmos-535," and "Kosmos-564"--"Kosmos-571." The "Kosmos" satellites are varied in design, composition, and in their basic and scientific apparatus; many of them have a system of orientation to the sun or earth (on several, in particular, an aerodynamic system of orientation is used); the energy supply of /42
the flight apparatus is provided by solar batteries and chemical sources of current (the work of the systems was checked with isotope generators); transfer of scientific and measurement information to the earth occurs with the aid of multichannel telemetry systems, which have flight memory devices. Several of the satellites are supplied with descent apparatus for return of the scientific apparatus and objects of the experiments to earth ("Kosmos-110," "Kosmos-186," "Kosmos-188," and others). A number of satellites are unified in the design and composition of their basic flight systems, which makes relatively easy the substitution of scientific apparatus for various modifications of the satellites. On the first satellites of the "Kosmos" series--"Kosmos-1," and "Kosmos-2"--a study was made of the structure of the ionosphere by radio methods; "Kosmos-3" and "Kosmos-5" are unmanned geophysical stations; on "Kosmos-4," in particular, radiation measurements were made during and after the American atomic explosion in space in the "Starfish" program; measurements on "Kosmos-7" allowed the assurance of radiation safety in flight of the "Vostok-3" and "Vostok-4" ships; on "Kosmos-26" the

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geomagnetic field was studied, and "Kosmos-97" had on board a quantum molecular generator, the experiment with which was important for distant cosmic systems of radio communications.

From February 22 through March 16, 1966 the biological satellite "Kosmos-110" was in geocentric orbit, with two experimental dogs, various biological objects, and scientific apparatus. The altitude of the apogee (904 km) ensured that the station would be in the zone of the radiation belt surrounding the earth. After a 22-day flight, on the 330th spiral, the satellite landed in the prescribed region. The successful fulfillment of the medical-biological experiment enriched our knowledge of the influence of increased radiation conditions in near space and prolonged weightlessness on the functional condition of the living organism.

On "Kosmos-122" the apparatus for meteorological observations was experimentally checked. The meteorological satellites "Kosmos-144," "Kosmos-156," "Kosmos-184," "Kosmos-206," and others are included in the "Meteor" system and are used to receive meteorological data for the weather service. In the joint flight of the satellites "Kosmos-186" and "Kosmos-188" on October 30, 1967 for the first time automatic approach and docking were made in orbit; after undocking, their autonomous flight was continued, and then landing was made in the territory of the U.S.S.R. On April 15, 1968, automatic docking was executed with the flight of "Kosmos-212" and "Kosmos-213"; both satellites also made a landing in the territory of the U.S.S.R. The "Kosmos-261" satellite, launched on December 20, 1968, was used for a scientific experiment on the study of the upper atmosphere of the earth and the nature of polar radiation. The scientific research institutes and observatories of the People's Republic of Bulgaria, the Hungarian People's Republic, the German Democratic Republic, the /43
Polish People's Republic, the Socialist Republic of Rumania, the U.S.S.R., and the Czechoslovak Socialist Republic took part in it.

The use of artificial earth satellites of the communications, meteorological, navigational, geodesic, geophysical, and astronomical types for the study of the earth's resources and other purposes opens new, broad possibilities for the solution of tasks of the national economy.

A space system of two scientific stations, "Electron-1" and "Electron-2," was launched in January 1964 by one rocket-carrier into various orbits, whose distance from the earth in apogee was approximately 7,000 and 70,000 km, respectively. In July 1964, the study was repeated on the stations "Electron-3" and "Electron-4." These systems of stations made a series of investigations: of the radiation belt of the earth, of the magnetosphere and the

outer layers of the earth's atmosphere, of the radiation of the sun, and of distant galaxies and cosmic rays.

The "Molniya-1" communications satellites, put into orbit in 1965-1973 with a period of revolution of 12 hours, with an apogee over the northern hemisphere of about 40,000 km and perigee of up to 500 km, ensured active transmission of distant television reports, and also distant bilateral telegraph, phototelegraph, and telephone communications (Moscow-Vladivostok, Murmansk, Arkhangel'sk, Krasnoyarsk, Yakutsk, Magadan, Yuzhno-Sakhalinsk, Ashkhabad, etc., Moscow-Paris). These satellites are part of the system of distant cosmic radio communications and work jointly with "Orbita" ground receiving radio stations, ensuring communications transmissions lasting 8 to 10 hours in a 24-hour period through each satellite. "Molniya-1" has an engine installation for correction of the orbit, which is done for the purpose of changing the period of the communications transmissions, and also for synchronization of the simultaneous movement of several satellites. The power of the "Molniya-1" flight transmitter (40 v) is substantially greater than on other well-known communications satellites. In flight the solar batteries are oriented on the sun, and the parabolic antenna on the earth.

With the aid of television apparatus set up on "Molniya-1," from May 1966 on images of the earth have been transmitted from altitudes of 30,000-40,000 km, giving information on the global distribution of the cloud cover; in 1967 for the first time a light image of the earth from space was obtained. In all, 23 "Molniya-1" satellites have been launched up to July 1, 1973, ensuring regular communications and television information in the territory of the U.S.S.R. and other countries.

For the further development of communications systems, beginning in November 24, 1971, satellites of the "Molniya-2" series were launched into orbit, with flight transmission apparatus ensuring the work of the system in a centimeter range of waves. On April 5, 1973, five "Molniya-2" satellites were put into orbit.

Meteorological satellites designed for regular collection of /44
meteorological information necessary for the operative work of the weather service, for development of theories of the general circulation of the atmosphere and the creation of reliable methods for long-term weather forecasts, and for international exchange, are also of exceptional practical value.

Among Soviet meteorological satellites are several satellites of the "Kosmos" series and the "Meteor" satellites. The testing of individual devices for meteorological satellites was done in 1963-1964 on satellites of the type of "Kosmos-23." In 1966

"Kosmos-122," with a complex of instruments for meteorological observations, was built and tested. With the launching of "Kosmos-144" and "Kosmos-156" (February 28 and April 27, 1967), the meteorological system "Meteor" began to function. The orbits of these satellites were nearly circular, at an altitude of about 600-700 km and an inclination of 81°. In flight the satellites are constantly oriented in the orbital system of coordinates (the longitudinal axis is directed on the vertical); and the flight apparatus is supplied with energy from solar batteries located in two panels, the surfaces of which are oriented to the system of tracking perpendicular to the direction of the sun's rays. In 1969-1973 15 "Meteor" satellites were put into orbit.

The parameters of the orbits of the meteorological satellites ensure observations of the weather in each of the observed regions at an interval of about 6 hours. The satellites are supplied with television and infrared apparatus for registration of images of the cloud, snow, and ice cover on the day and night sides of the earth and actinometric apparatus for measuring the radiation beamed and reflected by the atmosphere. The two satellites receive meteorological information from half of the surface of the earth during a 24-hour period. The meteorological data from on board the satellites are received by a network of ground points, equipped with methods of registration and processing of information and united by direct channels of communication with the Hydrometeorological Center of the U.S.S.R. The processing of information is automated and takes about 1.5 hours. The data received by the "Meteor" system substantially increase the reliability of weather forecasts, and permit the discovery of powerful cyclones and typhoons in the ocean, the choice of optimum routes for the merchant and fishing fleet, the definition of the boundary of the ice cover in Arctic regions, including the Northern Sea Route, the reception of information on regions of steady rains (for agriculture), etc.

In order to study the processes of solar activity and their influence on interplanetary space and the magnetosphere of the earth, in 1972 two automatic "Prognoz" stations were sent into high elliptical earth satellite orbits (with an apogee of 200,000 km).

A variety of geophysical rockets, high altitude research rockets, are the meteorological rockets systematically launched /45
by the U.S.S.R. since 1949 with the purpose of measuring the temperature, density, and pressure of the atmosphere, and the speed and direction of the wind at high altitudes. The rockets of the MR-1 type have a lift of 100 km, and those of the MR-12 type, of up to 180 km with a weight of the scientific apparatus of up to 50 kg. In their nose cones heat and membranous manometers, thermometers of resistance, bolometers, a radiotelemetric system,

accumulator batteries, and other equipment are installed. At the prescribed altitude the nose cone separates from the body, after which they descend by parachute.

Rockets of the M-100 type are two-stage, with powder engines in both stages, with a starting weight of 475 kg, a lift of 100 km, and with weight of the scientific apparatus of 15 kg. The small meteorological rockets MMR-06 are one-stage powder rockets, with a starting weight of 135 kg, a lift of 60 km, and a weight of the scientific apparatus of 5 kg. Launches of meteorological rockets are made both in the territory of the U.S.S.R. and in other regions (in the Arctic, the Antarctic, and in the oceans--from hydrographic ships).

Vertical probing is also done in the U.S.S.R. from high altitudes. The unmanned ionospheric laboratory "Yantar'-1" was launched at an altitude of 400 km with the aid of a geophysical rocket in October 1966 for study of the interaction of the jet stream of an electrical rocket engine (ER) with ionospheric plasma. The experimental plasma-ion ER was switched on at an altitude of 160 km, and during its further flight 11 cycles of work were completed. The registered speed of the jet stream was about 40 km/sec. The data obtained have great significance for solution of the problems of controllable flight of an apparatus with an ER in the upper atmosphere, at altitudes of 100 km and higher.

On October 12, 1967, a space probe was launched vertically to an altitude of 4,400 km, with the purpose of studying the upper layers of the atmosphere, the ionosphere of the earth and space around the earth; in particular, the radiation doses behind various shields during flight in the radiation belt. In order to obtain undistorted measurements, the station was constructed of special materials, and after the station was launched into the assigned trajectory the rocket-carrier was cast aside at a great distance with the help of an engine installation, thanks to which no gas flowed into the environment which was being studied. Besides the scientific apparatus, as usual, a radio telemetry system and apparatus for radio measurement of the trajectory were put on the station.

In 1963-1964 successful flight tests were conducted of the spaceships "Polet-1" and "Polet-2," which were automatically maneuverable into earth satellite orbits. In these tests the engines were switched on many times for stabilization and for making extended maneuvers of the spaceships by changing the plane of the orbit and the flight altitude.

An outstanding event in the development of Soviet science and technology was the creation in 1965 of the powerful "Proton"

rocket-space system. Its multistage rocket-carrier possesses several times greater lift capacity than the rocket-carrier "Vostok." The total maximum useful power of the engine installations of the rocket-carrier "Proton" exceeds 60 million hp, i.e., twice as great as for the "Vostok" rocket. /46

The birth of the "Proton" rocket-space system signified the beginning of a new stage in the study and conquest of space. New possibilities were opened for study of the planets and other heavenly bodies which form our solar system.

The "Proton" rocket-space system is based on the latest achievements of science and technology and is distinguished by high operational and energy characteristics.

The characteristics of a rocket, besides the perfection of its construction, are determined by the engines installed on it. On the rocket-carrier of the "Proton" system newly developed powerful engines are used, operating according to an improved scheme by which gas-generator gas discharged in the turbine is ignited in the chief combustion chamber, mixing it with an insufficient component of fuel. It is clear that thereby losses to the drive of the turbo-pumping system are practically nonexistent. This opened the possibility of achieving a pressure measuring hundreds of atmospheres in the combustion chamber. A significant pressure in the system of engines and ensurance of a high degree of completion of combustion, and also the realization of equal and equal-weight discharge of products of combustion out of the nozzles with a great degree of expansion allowed the creation of powerful, small-size engines with exceptionally high quality characteristics.

The brilliant design of the rocket as a whole, the building of perfected rocket engines, systems of control, and starting complexes represent the great success of Soviet rocket construction.

In 1965-1968 the heavy stations "Proton-1" were launched into geocentric orbits, equipped with scientific apparatus for the study of cosmic rays and the interaction with matter of particles of high and super-high energy. The weight of each of the first three satellites, launched on July 16 and November 2, 1965 and July 6, 1966 respectively, with equipment placed in the last stage of the rocket-carrier, was 12.2 tons, while the weight of the complex of scientific apparatus was 3.5 tons. Their orbits had a height of perigee of 190 km, with a height of apogee of about 630 km. As part of the scientific apparatus there was included an ionization calorimeter for studying particles with energy of up to 10^{13} eV. "Proton-4," launched on November 16, 1968, was equipped with a new, unique complex of

scientific apparatus, which allowed it to broaden the range of studied energies to 10^{15} eV. The weight of "Proton-4" without the last stage of the rocket-carrier was about 17 tons, and the weight of the complex of scientific apparatus was 12.5 tons. The orbit of "Proton-4" had a perigee of 255 km, and an apogee of 495 km. On satellites of the "Proton" series the energy spectrum and /47
chemical composition of primary cosmic rays, the intensity and energy spectrum of gamma rays and of electrons of galactic origin were studied.

The scientists had at their disposal new possibilities for experimentation, allowing them to penetrate more deeply into the secrets of the delicate structure of so-called elementary particles and to raise the curtain over nature and the origin of cosmic rays.

The successful completion in 1967-1968 on the heavy satellites "Kosmos-186," "Kosmos-188," "Kosmos-212," and "Kosmos-213" of automatic search, approach, docking, joint flight, and undocking was very promising. The whole complex of radio technical apparatus, of calculating-decision devices, of automatic systems and engine installations of satellites in the process of these experiments worked reliably.

The brilliant experiment on automatic docking of objects in space opened prospects for the creation of large space stations, their servicing, and the assembly while in orbit of powerful spaceships for interplanetary flights.

Development was begun of the "Soyuz" series of multiseat piloted space satellite-ships, designed for lengthy flights, maneuvering, approach, and docking in an earth satellite orbit. The "Soyuz" program plans broad scientific and technical studies in cosmic space around the earth and the creation of inhabited orbital stations.

The spaceship "Soyuz," weighing 6.45-6.65 tons, consists of an orbital section for making scientific experiments and a rest area for the cosmonauts; a descent apparatus--the cabin of the cosmonauts; and an instrument-system section with basic equipment and a correcting two-engine installation. The orbital section and the descent apparatus with a total volume of about 9 m^3 are reached by a pressure hatch. The descent apparatus has a heat-shield covering, and its form ensures controlled descent with the use of lift-drag ratio; in it are located the seats of the cosmonauts, the control console for the ship, systems of control of the descent, radio communications, life-support systems, parachute, powder engines for soft landing, etc. The g-loading in descent is reduced to 3-4 units and the accuracy of landing is substantially increased; the speed of landing on soft landing

does not exceed 2-3 m/sec. The system of orientation and control of motion ensures the orientation of the ship in space, the control and stabilization in the work of the rocket engine, approach to another ship and maneuvering near it; it can work automatically and in the regime of manual control. The spaceship is supplied with a system for automated docking, previously checked in the pair flights of the unmanned "Kosmos" satellites. The energy supply of the flight apparatus comes from solar batteries located on two opening panels. The complex of radio technical devices determines the parameters of the orbit, reception of commands from earth, bilateral radio communications with the earth, and the transmission of television images of the normal standard (there are 4 cameras on board), and of telemetric information. The equipment of the ship ensures the possibility of its completely autonomous flight and piloting, and the characteristics of the engine installation allow maneuvers to be accomplished at an altitude of up to 1,300 km. /48

The path to the conquest of space is thorny. On April 24, 1967, in testing a new spaceship, "Soyuz-1," during landing on the earth after a 24-hour space flight, the talented cosmonaut V. M. Komarov perished tragically (due to failure of the parachute system). Previously V. M. Komarov had made a flight on the "Voskhod" ship.

"Soyuz-2" was launched into orbit on October 25, 1968. At its passage over the cosmodrome on October 26 the "Soyuz-3" ship, piloted by cosmonaut G. T. Beregovoy, was launched. "Soyuz-3" made a radio search for "Soyuz-2" and an automatic approach to it up to a distance of 200 m. The subsequent approach and maneuvering of "Soyuz-3" near "Soyuz-2" was done by the cosmonaut with the use of a system of manual control. On completion of the experiments, "Soyuz-2" and later (October 30) "Soyuz-3" made a landing in the prescribed region of the Soviet Union.

"Soyuz-4" was launched into orbit on January 14, 1969, with the pilot V. A. Shatalov on board, and on January 15, 1969, "Soyuz-5" was launched into orbit with the following crew: ship's commander V. V. Volynov, flight engineer A. S. Eliseyev, and engineer-researcher Ye. V. Khrunov. On January 16 automated approach of the "Soyuz-4" and "Soyuz-5" ships and their manual docking was accomplished. The first experimental space station was assembled and began to function in orbit. After docking, A. S. Eliseyev and Ye. V. Khrunov in space suits with autonomous life-support systems went out into space for a period of 37 minutes and transferred to "Soyuz-4." The altitude of the flight of the experimental station in apogee was 250 km, and the total weight of the station was 12,924 kg. Then the spaceships undocked and continued individual flight. During the flight, scientific-technical and medical-biological studies took place: observations

of geological-geographical objects of the earth's surface and of heavenly bodies, television reporting from on board the ships, movies and photographs, navigational measurements, etc. After execution of the flight program, on January 17, "Soyuz-4" with three cosmonauts and, on January 18, 1969, "Soyuz-5" with V. V. Volynov made a descent and landed in the territory of the U.S.S.R.

On October 11, 1969 "Soyuz-6" was launched into orbit with this crew: ship's commander G. S. Shonin and flight engineer V. N. Kubasov who executed a broad program of scientific studies, and also experiments on various methods for welding various metals under conditions of a deep vacuum and weightlessness. Welding of thin sheets of stainless steel and titanium, cutting of stainless steel, titanium and aluminum, and processing of nonmetallic materials were accomplished.

"Soyuz-7" was launched into orbit on October 12, 1969 with this crew: ship's commander A. V. Filipchenko, flight engineer V. N. Volkov, and engineer-researcher V. V. Gorbatko. The crew of the ship made maneuvers in orbit jointly with "Soyuz-6," made navigational observations in group flight, and performed various scientific experiments and observations. /49

On October 13, 1969, "Soyuz-8" was launched into near orbit with a crew consisting of ship's commander V. A. Shatalov and flight engineer A. S. Eliseyev.

In the course of the group flight of the three ships with the family of cosmonauts, complex one-time scientific experiments were made in space around the earth according to a broad program, reciprocal maneuvering, testing the system of control in group flight using three spaceships. As a result of the maneuvering, "Soyuz-6" and "Soyuz-8" in turn approached "Soyuz-7" at a distance of several hundreds of meters. The parameters of the orbits of the three ships were close; on the average, the height of the perigee was 200 km, of the apogee, 225 km, the inclination was 51.7°, the period of revolution 88.6 minutes. In addition, mutual action of a group of spaceships with ground command-measurement centers located in various regions of the U.S.S.R. and on scientific-research ships of the U.S.S.R. Academy of Sciences in a number of points of the World Ocean was developed.

After completion of the program of work, in the prescribed region near Karaganda "Soyuz-6" landed on October 16, "Soyuz-7" on October 17, and "Soyuz-8" on October 18, 1969. The total duration of the experiment in space was 7 days, with a duration of flight for each spaceship of 5 days.

The spaceship-satellite "Soyuz-9" with a crew consisting of ship's commander A. G. Nikolayev and flight engineer V. I.

Sevast'yanov made a flight on June 1-19, 1970, lasting 425 hours. In flight the trajectory was corrected twice and a broad program of scientific-technical and medical-biological studies was executed.

A. G. Nikolayev, who made flights on the "Vostok-3" and "Soyuz-9" ships, remained in space for 519 hours.

The experience of two cosmonauts who were, for almost 18 days, in an uninterrupted state of weightlessness, helps to solve the difficult problem of long-term stay of man in orbital stations and on interplanetary flights.

The long-lasting orbital scientific station "Salyut" was in an earth satellite orbit from April 19 through October 11, 1971. The flight of the orbital station, which lasted almost six months, consisted of several stages. In the first stage the station flew jointly with the spaceship "Soyuz-10," piloted by a crew consisting of cosmonauts V. A. Shatalov, A. S. Eliseyev, and N. N. Rukavishnikov, which was launched on April 23. With this flight a check was made of the functioning of the perfected systems which ensured search, approach, mooring, and docking and undocking of the ship and the station. After joint flight in a docked situation, lasting 5 hours 30 minutes, the ship separated from the station and on April 25, 1971, it landed. In all, the "Soyuz-10" spaceship made more than 30 revolutions around the earth. /50
The subsequent work of the orbital stations took place in an automated regime. The second stage of the space experiment began on June 6, 1971, with the launching of the "Soyuz-11" transport ship with a crew consisting of ship's commander G. T. Dobrovol'skiy, flight engineer V. N. Volkov, and engineer-test pilot V. I. Patsayev. After docking with the ship of the "Salyut" station, it became the first long-lasting piloted orbital scientific station. Its weight exceeded 25 tons.

During the 23-hour flight of the piloted station, the crew made complex scientific-technical and medical-biological studies, which represented a great contribution to the development of lengthy orbital piloted flights and which yielded important scientific results. The complete duration of the flight of the crew in the ship and on the station was 570 hours.

After completing the program, the cosmonauts transferred to the "Soyuz-11" ship and undocked from the "Salyut" station, which was again transferred to work in an automated regime. During descent, after work of the engine braking device, during separation of the descent apparatus, complete depressurization took place, which led to the death of the cosmonauts. Following the program laid out, the descent apparatus made a soft landing in the prescribed region.

Along with the development and expansion of work on conquest of space, the number of deaths of cosmonauts, obviously, will increase. But mankind will never forget their exploits.

During the period of 1961-1971, 25 Soviet cosmonauts made oribtal geocentric flights on one-, two-, and three-passenger piloted spaceships of three types: "Vostok" (6), "Voskhod" (2), and "Soyuz" (10 ships), and the orbital station "Salyut."

The very valuable, broad scientific information received from Soviet vertical probes, satellites. interplanetary unmanned stations, and piloted spaceships, after processing, is published in printed editions and becomes accessible to the world scientific public.

The Soviet Union has been cooperating with various countries in the study of space by rocket systems, beginning with the organization of joint observations of the first Soviet artificial earth satellites in 1957. "Interkosmos," the Council on International Cooperation in the Field of the Study and Use of Outer Space under the U.S.S.R. Academy of Sciences, has concluded multilateral and bilateral agreements.

In 1967 a program was adopted for "Cooperation of Socialist Countries in the Study and Use of Space for Peaceful Purposes," which plans to conduct scientific research work. The People's Republic of Bulgaria, the Hungarian People's Republic, the German Democratic Republic, the Republic of Cuba, the Mongolian People's Republic, the Polish People's Republic, the Socialist Republic of Rumania, the U.S.S.R., and the Czechoslovak Socialist Republic became members. The organization's purposes include the study of the physical properties of space and the upper atmosphere, satellite meteorology, space communications, space biology and medicine, launchings of satellites and rockets, the conduct of conferences, symposia, meetings of staffs, and mutual visits by scientists from institutions taking part in joint studies. /51

The first space apparatus launched on December 20, 1968, under the "Cooperation" program was the "Kosmos-261" satellite, which was used for the study of the upper atmosphere of the earth and the nature of the northern lights. Along with joint work on satellites launched by the Soviet Union in accordance with its own programs, since 1969 launches have been made of satellites and geophysical rockets with the apparatus of the socialist countries. The first such satellite--"Interkosmos-1"--was launched on October 14, 1969, for study of ultraviolet and X-ray radiation of the sun and the influence of these radiations on the structure of the upper atmosphere of the earth. The scientific apparatus on board was developed and produced in the G.D.R., the U.S.S.R, and in the Czechoslovak S.S.R. Specialists from these countries took part

in the setting up and testing of the apparatus on the satellite while it was being prepared for launch and in the operative group for control of the flight of the satellite.

"Interkosmos-2" was launched on December 25, 1969, to study the characteristics of the ionosphere of the earth. In 1970-1972 six more apparatuses of the "Interkosmos" series were launched into an earth satellite orbit, continuing joint investigations in accordance with a broad program.

On April 19, 1973 the AES "Interkosmos-Copernicus 500," equipped with scientific apparatus, was launched into orbit. This space experiment, prepared by Polish and Soviet specialists, was dedicated to the 500th anniversary of the birth of the great Polish scientist Nikolay Copernicus.

The launches of the geophysical rockets "Vertical-1" (November 20, 1970) and "Vertical-2" (August 20, 1971), carrying scientific apparatus developed by the socialist countries, allowed complex studies to be made of the radiation of the sun and the absorption of this radiation in the atmosphere, of the parameters of the ionosphere and of meteor particles. The weight of the nose cone of the rocket, including the rescue container, was about 1,300 kg, and the altitude of vertical lift was 463-487 km.

On June 30, 1966 an agreement was concluded between the U.S.S.R. and France on cooperation in the field of the scientific study of space, of space communications, space meteorology and aeronomy, which stipulated work on establishing a light telebridge between Paris and Moscow by using "Molniya-1" satellites, by using Soviet instruments on French rockets and French instruments on Soviet rockets.

Apparatus developed in France was installed on the "Lunokhod-1" and "Lunokhod-2" apparatuses (an angular laser reflector), and on the interplanetary station "Mars-3" ("Stereo"--for study of /52
the structure of radio radiation of the sun in a meter range of waves). On December 27, 1971 in the Soviet Union the artificial earth satellite "Oreol" was launched for the study of physical phenomena in the upper atmosphere of the earth in high latitudes and the study of the nature of the northern lights. The scientific apparatus and the program of the experiment were developed by Soviet and French specialists within the framework of the joint Soviet-French "Arkad" project.

On April 4, 1972, one rocket-carrier sent into orbit with an apogee of 39,260 km the communications satellite "Molniya-1" and the French "MAS," designed to study the characteristics of various solar batteries in space conditions.

An important and very promising step is the agreement between the U.S.S.R. and the U.S.A. on execution of the joint "Soyuz-Apollo" program. This program plans the docking in orbit around the earth of the spaceships "Soyuz" and "Apollo" in July 1975, their joint flight, the transfer of the cosmonauts from one ship to another, and undocking with subsequent landing.

The development of all-purpose technical methods which are here necessary for approach and docking of the ships and ensuring the transfer of the cosmonauts opens the possibility of Soviet and American scientists making joint experiments in space, and also of giving mutual aid or rescue to a crew in need.

As space around the earth, moon, and other heavenly bodies is further conquered, the problem of giving mutual aid to cosmonauts of various countries acquires important significance.

In Article V of the agreement "On the Principles of Action of Countries in the Study and Use of Space . . .," concluded in 1967, and also in the international agreement on rescue of cosmonauts, the return of cosmonauts and objects launched into space in case of accident, trouble, or forced landing (1968), the necessary legal norms are stipulated. But the development of problems of space law is just beginning.

Having completed a short survey of the chief events in the development of rocket construction and cosmonautics in the U.S.S.R., it is necessary to note that many events and names, more or less important, for various reasons have not been mentioned.

In the glorious ranks of the numerous pioneers of Russian rocket construction, it is necessary especially to note the pioneers of rocket-space technology, and first of all K. E. Tsiolkovskiy, whose prophetic studies were supplemented by Yu. V. Kondratyuk, F. A. Tsander, and others, and, later, S. P. Korolev, jointly with the chief designer of engines, the chief designer of a control system, and others who made real the dreams of many generations for flights of man into space; and, of course, the first cosmonaut Yu. A. Gagarin with his brilliant followers. The names of M. K. Yangel', A. M. Isayev, S. A. Kosberg, and G. N. Babakin have entered forever the history of Soviet rocket-space technology.

In the U.S.S.R. museums and exhibits of rocket-space technology, designed to illumine the path to the stars traversed by Soviet science and technology, have been built and are being improved. First of all the K. E. Tsiolkovskiy State Museum of the History of Cosmonautics in Kaluga, the House-Museum of K. E. Tsiolkovskiy in Kaluga, the Memorial Museum of Cosmonautics in /53

Moscow, the "Kosmos" Pavilion of the Exhibit of the Achievements of the National Economy, the Polytechnical Museum in Moscow, the Central House of Aviation and Cosmonautics in Moscow, the Museum of the Gaseodynamics Laboratory in the Petropavlovsk Fortress in Leningrad, the House-Museum of N. I. Kibal'chich in Korol', of Yu. A. Gagarin in the city of Gagarin, of S. P. Korolev in Zhitomir, the exhibits in the planetariums, and many others must be mentioned.

Following the U.S.S.R., which on October 4, 1957, opened the space age by launching into orbit the first artificial earth satellite, the U.S.A. emerged into space by launching on February 1, 1958, its first satellite, "Explorer-1." France became the third space power, creating, on November 26, 1965, its "Asterix-1" earth satellite. In 1970 on February 11 Japan launched into orbit the satellite "Osumi," and on April 25 a Chinese artificial earth satellite went out into space. The sixth country was England, which created its rocket-carrier with the help of which on October 28, 1971, it launched into orbit the satellite "Prospero." The European community and other countries are also doing work with the purpose of putting satellites into geocentric orbits by their own efforts. Many countries are creating national space programs.

The U.S.A. has achieved brilliant successes in recent years. In 1958-1972 about 700 American artificial earth satellites of various types--research, meteorological, communications, biological, navigational, geodesic, geophysical, astronomical, and others--have been launched. The satellites were launched into various geocentric orbits, including stationary ones. Programs of study of the moon with the aid of automatic apparatuses for hard landing, the "Ranger" (3 flights in 1964-1965), "Survevor" soft landing apparatuses (five landings in 1966-1968), and "Lunar Orbiter" moon satellites (five satellites in 1966-1967) have been launched. A series of automatic space probe-satellites of the sun, "Pioneer," has been launched. "Pioneer-10," after flying past near Jupiter, will go out of the bounds of the solar system. The "Mariner" automated interplanetary stations were used for flying around Venus (in 1962 and 1967) and Mars (1965, and twice in 1969), and also for creating the first artificial satellite of Mars (1971) with the purpose of studying these planets at close range. As a result results have been obtained which constitute an outstanding contribution to science; for example, the chief radiation belt of the earth was discovered (Van Allen), craters were discovered on Mars, and much more.

Piloted flights were made in the U.S.A. on ships of three types: one-passenger "Mercury" weighing 1.3-2 tons--2 suborbital flights in 1961 and 4 in geocentric orbits in 1962-1963; two-passenger "Gemini" weighing 3.2-3.8 tons--10 flights in geocentric

orbits in 1965-1966; and three-passenger "Apollo weighing up to 46.8 tons--11 flights in geocentric orbits in 1968-1972, and 3 flights around the moon and 6 expeditions onto the surface of the moon. /54

In flights on "Gemini" ships maneuvers were made in orbit for the first time with manual control, and close approach of space ships, joining the ship to the target by cable, their manual docking, and a duration of almost 14 days of uninterrupted flight were attained

The "Saturn-5" heavy rocket-carrier, with a starting weight of up to 3,000 tons, launched into geocentric orbit a mass of up to 135 tons, including the third stage of the rocket, which permitted a piloted flight around the moon and a lunar expedition for the first time.

The 11-day flight of the spaceship "Apollo-7" around the earth with the astronauts W. Schirra, W. Cunningham, and D. Eisele, permitted the reliability of the ship's systems to be verified. A historic event was the flight around the moon with return to earth on December 21-27, 1968, of the spaceship "Apollo-8" with astronauts F. Borman, G. Lovell, and W. Anders. The ten-day flight of the "Apollo-9" ship with astronauts G. Mcdivitt, D. Scott, and R. Schweikart in geocentric orbit served mainly to test the systems for the lunar module of the ship. The flight around the moon with emergence into selenocentric orbit was repeated according to a more complex program by the "Apollo-10" ship with astronauts T. Stafford, J. Young, and E. Cernan.

The flight to the moon and return to earth on July 16-24, 1969, by the "Apollo-11" spaceship with a crew consisting of N. Armstrong, E. Aldrin, and M. Collins will go into the annals of the history of mankind. On July 20-21 the first men on the moon--Neil Armstrong and Edwin Aldrin (Michael Collins remained in selenocentric orbit)--stayed for 21 hours, 36 min on the lunar equator in the Sea of Tranquillity. Outside the ship on the lunar surface, N. Armstrong in the course of 2 hours, 31 min, and E. Aldrin for 2 hours, executed a program of studies.

The second flight to the moon to study it in an expanded program was successfully executed on November 14-25, 1969 on "Apollo-12" by astronauts C. Conrad, R. Gordon, and A. Bean. The lunar module of the spaceship with astronauts C. Conrad and A. Bean landed on the moon on November 19 in the Ocean of Storms and stayed there for 31 hours, 31 min. The astronauts twice went out of the spaceship onto the lunar surface, studying it for a total of 7.5 hours each.

The flight of the "Apollo-13" spaceship with astronauts J. Lovell, J. Swigert, and F. Haise, due to an emergency situation on board, was limited to flight around the moon with return to earth.

The third landing on the moon took place in the flight of the "Apollo-14" ship with a crew consisting of A. Shepard, S. Roosa and E. Mitchell, and lasted from January 31 through February 9, 1971. During February 5-6 A. Shepard and E. Mitchell stayed for 33 hours, 30 min in the intersecting continental region of the Fra Mauro Crater, executing a wide program of study of this region during two moon walks. The first walk lasted 4 hours, 47 min, and the second 4 hours, 35 min. /55

A wider program of study of the moon was realized during the fourth landing, which was made in the flight of the perfected "Apollo-15" spaceship, with astronauts D. Scott, A. Worden, and D. Irwin on July 26-August 7, 1971. D. Scott and D. Irwin stayed for 66 hours, 55 min (July 30-August 2) in the landing region, located beween Hadley Furrow and the Apennine Mts. During three moon walks lasting a total of 18 hours, 36 min, the astronauts covered 27.2 km on a lunar vehicle and executed a full program of studies.

The fifth expedition was made on April 16-27, 1972. The lunar module of the "Apollo-16" ship with astronauts J. Young and C. Duke made a landing in the region of Descartes Crater and remained on the moon 71 hours, 2 min. The astronauts made three moon walks lasting a total of 20 hours, 14 min, and trips on the lunar vehicle. T. Mattingly was in selenocentric orbit.

The sixth expedition was made on December 7-19, 1972. It completed the "Apollo" program of flight to the moon. The lunar module of the "Apollo-17" with astronauts E. Cernan and H. Schmitt made a landing on the edge of the Sea of Clarity and stayed on the moon for 75 hours. R. Evans was in selenocentric orbit.

As a result of the six lunar expeditions, about 400 kg of lunar rocks were brought to earth.

To mark the successful fulfillment of flights to the moon in the "Apollo" program, a large crater on the far side of the moon was given the name of this program.

By the end of 1972 space flights were made by 34 astronauts of the U.S.A. on 25 orbital spaceships. Flights into space were made by 59 Soviet and American cosmonauts in 45 spaceships and 1 orbital station.

In order to immortalize the cosmonauts who made a basic contribution to the development of cosmonautics, their names were given to several craters on the far side of the moon, both posthumously--Gagarin, Komarov, Belyayev, Grissom, White, and Chaffee--and to living cosmonauts--Titov, Nikolayev, Tereshkova, Feoktistov, Leonov, Shatalov, Borman, Lovell, Anders, Armstrong, Aldrin, and Collins.

Only about 15 years have passed since the day of the first breakthrough into space, the beginning of the space era in the history of mankind. Despite the greatness of what has been achieved, only the first steps have been made. We are on the very threshold of entrance into space.

All the countries of the world are interested in peaceful penetration into space and its conquest for the welfare of all mankind. The conclusion of a treaty by all countries on principles of activity of countries in the study and use of space, including the moon and other heavenly bodies, approved in 1967 by /56 the General Assembly of the U.N., will go down in history as an outstanding progressive event.

In accordance with this historic treaty, from now on space, including the moon and other heavenly bodies, is open for study and use by all countries, and is not subject to national appropriation, either by proclaiming sovereignty or by occupation, or by any other methods. The participating countries in the agreement are bound not to send into orbit around the earth any objects with nuclear weapons or any other types of weapons of mass destruction, not to set up such weapons on heavenly bodies and not to place such weapons in space in any other manner. The moon and other heavenly bodies are to be used exclusively for peaceful purposes. The creation of military bases, buildings and fortifications on heavenly bodies, the testing of any types of weapons and the conduct of military maneuvers are forbidden.

The agreement is permeated with the spirit of cooperation and mutual aid of the countries working on the problem of direct penetration into space.

The development of human society must be harmonious. The possession of the secrets and the energy of space will make man so powerful that for intelligent use of all the possibilities he must rise to a new, higher stage of intellectual development.

The nation of Soviets is proud of the fact that its sons and daughters have cut a window through to the universe, have opened for mankind a path into space and have made a pioneering contribution to the study of world space by jet instruments.

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The building of the Main Admiralty (Leningrad). To the right of the arch on the second floor was located the design bureau for electrical and liquid-fuel rocket engines of the GL. (upper) /64

Petropavlovsk Fortress (Leningrad). In the building of the Johannes Ravelin was located the testing station and the shops of the GL. (lower)

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The first artificial earth satellite in the world. Launched into orbit on October 4, 1957. (right) /73

The Soviet V2A geophysical rocket, which lifted a useful payload of 2,200 kg to an altitude of 212 km. The length of the rocket--20 m, diameter of the body--1.66 m (1957). (left) /74

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The third Soviet artificial earth satellite. Launched into orbit on May 15, 1958. (upper) /75

The second artificial earth satellite in the world. Launched into orbit on November 3, 1957. (lower)

The "Luna-1" unmanned station--the first artificial satellite of the sun. Launched on January 2, 1959. (upper left) /76

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Fragment of a lunar panorama transmitted to earth by the "Luna-9" automated station (1966). (lower)

The first complete map of the moon, composed in 1966 with the aid of photographs obtained from the automated stations "Luna-3" and "Zond-3." (upper) /78

The "Luna-16" station, which for the first time brought automatically from the moon to the earth samples of lunar rock on September 24, 1970. (lower left)

Samples of lunar rock brought to earth by the automatic station "Luna-16" (1970, (lower)

Photograph of the earth from a distance of around 90,000 km, furnished by the unmanned spaceship "Zond-5" on September 21, 1968. (right) /79

The unmanned "Luna-10" station--the first artificial satellite of the moon. Launched into orbit on April 3, 1966. (lower)

"Lunokhod-1," which made investigations on the lunar surface (1970-1971). (upper) /80

The "Luna-17" unmanned station, which brought to the moon the "Lunokhod-1," controllable from the earth, on November 17, 1970. (lower)

The "Mars-1" unmanned station, which began flights to Mars, launched November 1, 1962. (upper) /81

The "Venus-3" unmanned station, which for the first time reached the surface of Venus on March 1, 1966. (middle)

The "Mars-3" unmanned station, the descent apparatus of which on December 2, 1971 made a soft landing on Mars. (lower)

Yuriy Alekseyevich Gagarin (left) /82

The satellite spaceship "Vostok" (upper)

Space walk of A. A. Leonov from the spaceship "Voskhod-2," March 18, 1965. (upper) /83

Pilot-cosmonauts of the U.S.S.R, who flew on the satellite spaceships "Vostok" and "Voskhod" (group photo). Above (left to right): Yu. A. Gagarin, V. F. Bykovskiy, B. B. Yegorov, P. I. Belyayev, P. R. Popovich, V. M. Komarov. Below: K. P. Feoktistov, V. V. Tereshkova-Nikolayeva, A. A. Leonov, A. G. Nikolayev, G. S. Titov. (lower)

The three-stage rocket-carrier "Vostok," flying since May 15, 1960. (left) /84

The four-chamber RD-107 engine of the first stage of the rocket-carrier "Vostok," with a thrust of 102 tons, with two rudder engines using oxygen-kerosene fuel, pressure in the combustion chamber--60 atm. Developed in 1954-1957 at the OKB-EDB. (right)

Sergey Pavlovich Korolev (upper left) /85

Mikhail Kuz'mich Yangel' (upper right)

Aleksey Mikhailovich Isayev (lower left)

Georgiy Nikolayevich Babakin (lower right)

Two-stage "Kosmos" rocket-carrier, length--30 m, diameter--1.65 m. Flying since 1962. (right) /86

An RE-119 engine of the second stage of the "Kosmos" rocket-carrier, with thrust of 11 tons, with a system of rudder control, using oxygen-dimethylhydrazene propellant; pressure in the combustion chamber--80 atm, specific impulse--352 sec. Developed in 1958-1962 at the GL-EDB. (left)

Four-chamber RE-214 engine of the first stage of the "Kosmos" rocket-carrier with a thrust of 74 tons using nitric-acid-carbon fuel. Developed in 1952-1957 at the GL-EDB. (lower)

Some scientific space stations of the "Kosmos" series. 1--"Kosmos-137," for study of the radiation belt of the earth; 2--"Kosmos-97"--with a molecular generator on board; 3--"Kosmos-3," for study of low-energy particles; 4--"Kosmos-2" for study of the ionosphere. /87

Artificial communications earth satellite "Molniya-1" (1965-1973). (upper) /88

Meteorological artificial earth satellite "Kosmos-144" (1967). (middle)

Vertical space probe, lifted on October 12, 1967 to an altitude of 4,400 km. (lower)

Unmanned scientific station "Proton-4," with a diameter of more than 4 m, weighing about 17 tons, sent into heliocentric orbit on November 16, 1968. (upper) /89

Complexes of scientific apparatus of artificial earth satellites "Proton-1 to 3" (right) and "Proton-4" (1965-1968) (lower).

The "Kosmos-186" and "Kosmos-188" satellites at the final stage of automated approach (1967). (upper) /90

The "Soyuz" orbital station (1969-1970). (lower)

The rocket-carrier with the "Soyuz" spaceship, flying since 1967, at the starting area of the cosmodrome. /91

Pilot-cosmonauts of the U.S.S.R., who flew on "Soyuz" satellite-spaceships. First row, left to right: G. T. Beregovoy, V. A. Shatalov, B. V. Volynov, A. S. Eliseyev, V. N. Volkov, V. V. Gorbatko, A. G. Nikolayev, Ye. V. Khrunov. Second row, left to right: G. S. Shonin, V. N. Kubasov, A. V. Filipchenko, V. I. Sevast'yanov, G. T. Dobrovol'skiy, V. I. Patsayev. /92 /93

The scientific research earth satellite "Interkosmos-1" (1969) (upper) /94

Long-lasting orbital station "Salyut" (1971) (lower)

Takeoff of a "Kosmos" rocket-carrier with an artificial earth satellite "Interkosmos" (1969-1973). /95